

CELEBRATING 60 YEARS IN SPACE: GAGARIN & SHEPARD p. 24

NOVEMBER 2021

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WITH SKETCHES** p. 40

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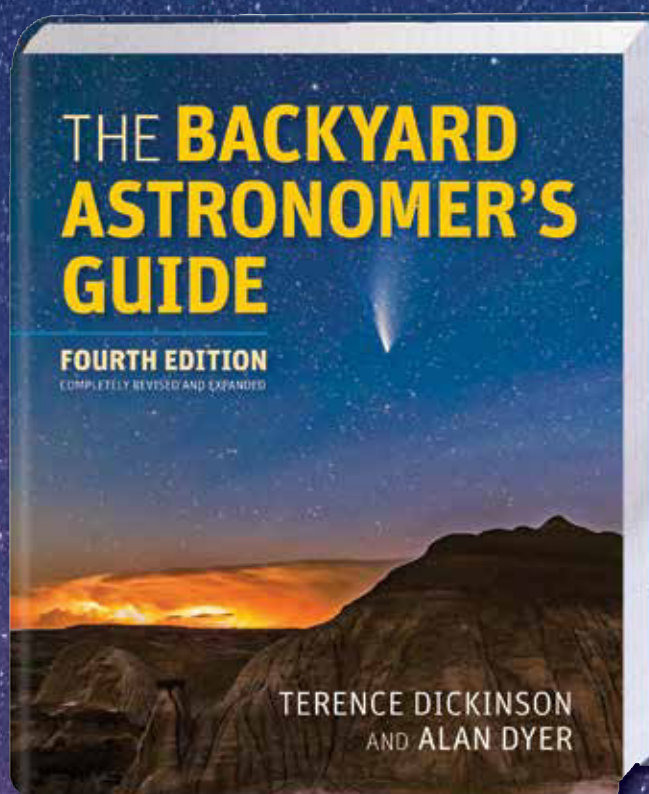
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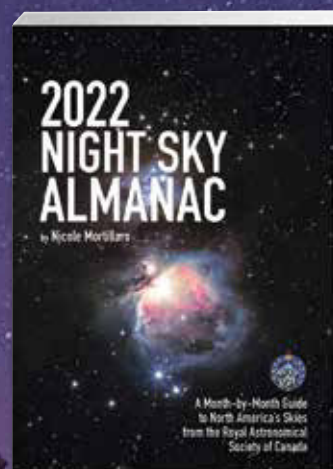
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ON THE COVER

Since the arrival of Mariner 9 some 50 years ago, Mars has fascinated us like no other world. [USGS](#)

COLUMNS

Strange Universe 14

BOB BERMAN

Secret Sky 15

STEPHEN JAMES O'MEARA

Binocular Universe 58

PHIL HARRINGTON

Observing Basics 59

GLENN CHAPLE

7

QUANTUM GRAVITY

Everything you need to know about the universe this month: Billionaires race to space, the space station spins, a look at black hole jets, and more!

IN EVERY ISSUE

From the Editor 5**Astro Letters 6****Reader Gallery 62****Advertiser Index 65****Breakthrough 66**

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Media Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187-1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, PO Box 8520, Big Sandy, TX 75755. Canada Publication Mail Agreement #40010760.



CONTENTS

54

FEATURES

16 COVER STORY
50 years on Mars

The current international fleet of explorers follows the path blazed by NASA's pioneering Mariner 9 mission.
JIM BELL AND WILLIAM SHEEHAN

24
Celebrating 60 years of human spaceflight

The flights of Yuri Gagarin and Alan Shepard blazed a trail for human spaceflight that is still unfolding today.

BEN EVANS**32**
Sky This Month

A dazzling evening lineup.
MARTIN RATCLIFFE AND ALISTER LING

34
Star Dome and Paths of the Planets

RICHARD TALCOTT;
ILLUSTRATIONS BY ROEN KELLY

40
Sketching the Sun with AI

The oldest method of recording the Sun has some new artificial-intelligence tricks. **MARK ZASTROW**

44
Flying into June's ring of fire eclipse

Take a journey through the Moon's shadow.

JAY M. PASACHOFF**48**
Astrophotography with your smart phone

You don't need top-tier equipment to image the night sky through your telescope. Your phone can do the trick.

MICHAEL WEASNER**54**
Catch this month's lunar eclipse

To enjoy a spectacular Blood Moon, all you need is a clear sky.

MICHAEL E. BAKICH**60**
Ask Astro

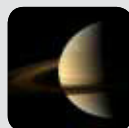
Black hole spaghetti.

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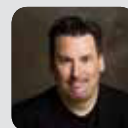
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The latest updates from the science and the hobby.

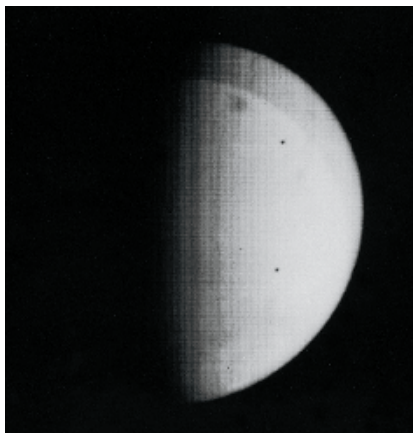
**Sky This Week**

A daily digest of celestial events.



Dave's Universe
The inside scoop from the editor.

Space anniversaries



We met the Red Planet in a new way when the Mariner 9 probe entered its orbit in 1971. USGS



Fifty years ago, Mariner 9 made history. Launched May 30, 1971, the NASA-made probe entered an orbit around Mars on Nov. 14 of that year — the first craft to orbit another planet. Mariner 9 barely beat a pair of Soviet spacecraft, Mars 2 and Mars 3, to the punch, the latter arriving at the Red Planet a few weeks later. So the space race carried on.

We have now spent 50 years on Mars. Mariner 9 opened our eyes, finding the martian atmosphere thick and dusty, the planet's surface heavily obscured. Eventually, the probe returned more than 7,300 images covering 85 percent of the planet's surface. A strange

new world emerged, with riverbeds, huge volcanoes, canyon systems, and abundant craters. Evidence of wind and water erosion was displayed throughout many of the images.

Planetary scientist Jim Bell recalls those early, heady days of Mars exploration in "50 years on Mars" (page 16), co-authored with William Sheehan. Bell is a professor at Arizona State University and has been integrally involved in multiple Mars missions, including the Curiosity, Spirit, and Opportunity rovers.

A decade before Mariner 9, the world had first awoken to the frontiers of space. On April 12, 1961, now 60 years ago, Soviet cosmonaut Yuri Gagarin sat inside the Vostok 1 spacecraft and rode into space, orbiting Earth for 108 minutes. He became the first human to enter space, winning the first big milestone of the space race and opening the era of space exploration to come.

Three weeks later, on May 5, 1961, Alan Shepard became the first American to ride into space, inside the capsule *Freedom 7* aboard a Mercury-Redstone rocket. His suborbital journey lasted 15 minutes. Our story "Celebrating 60 years of human spaceflight" (page 24), by space journalist Ben Evans, recounts those earliest days of adventure into space.

I hope you'll enjoy Evans and Bell's stories, reminders of humanity's spirit of curiosity as we push forward into a new era of discovery, as much as I did.

Yours truly,

David J. Eicher
Editor



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Nearly 50 years after the impact, evidence shows Mars may have been impacted by ice comets. NASA/JPL-CALTECH

News note

Evidence is presented in a report published in the *Journal of the Association of Lunar & Planetary Observers* (Summer 2020) that a comet consisting of large amounts of ice probably impacted Mars on Sept. 2, 1973. Four members of the McDonnell Douglas Amateur Astronomers Club observed the aftermath of the proposed comet impact, and provided three items of evidence. These include telescopic observations of white clouds that

would have happened after the impact, shock waves that lifted airborne dust over a region, and six new craters. — **Jim Melka**, assistant Mars coordinator of the **Association of Lunar & Planetary Observers**

Travel via light

My name is Brady and I'm in ninth grade. I would like to tell you that I enjoyed the "Breakthrough Starshot" article from your May 2021 issue. It just makes me

so happy knowing that one day we could be traveling using light. I enjoyed how it talked about how the lightsail works and how the article talked about the statistics and how fast it goes or how it works, all the while making it simple enough to understand.

I really like the magazines you make. Keep up the great work! I look forward to reading your next magazine. — **Brady**, Fredrick, MD

A reachable destination

How lucky we are to have the Moon! Your July issue with the article on Apollo 15 reminded me of this. Yes, the Moon helps stabilize Earth's orbit, and probably had quite the part in the evolution of life. But just consider space travel if we had no Moon. Any longer distance trips for humans would have to have technology advanced enough to reach Mars in one leap. A big ask — 50 plus years after Apollo, we still haven't done it. — **Frank Coulter**, Pauanui Beach, New Zealand

Correction

The May 2021 article "Breakthrough Starshot: A voyage to the stars" incorrectly stated Yuri Milner is Russian. He is in fact Israeli-Russian.

→ We welcome your comments at *Astronomy Letters*, P.O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

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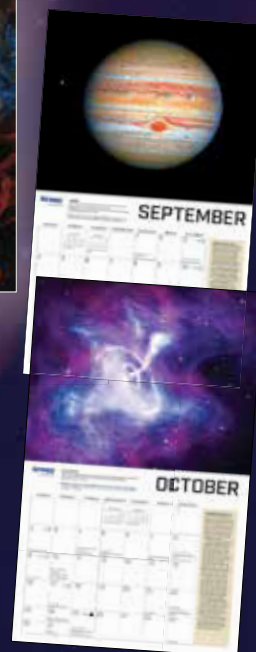
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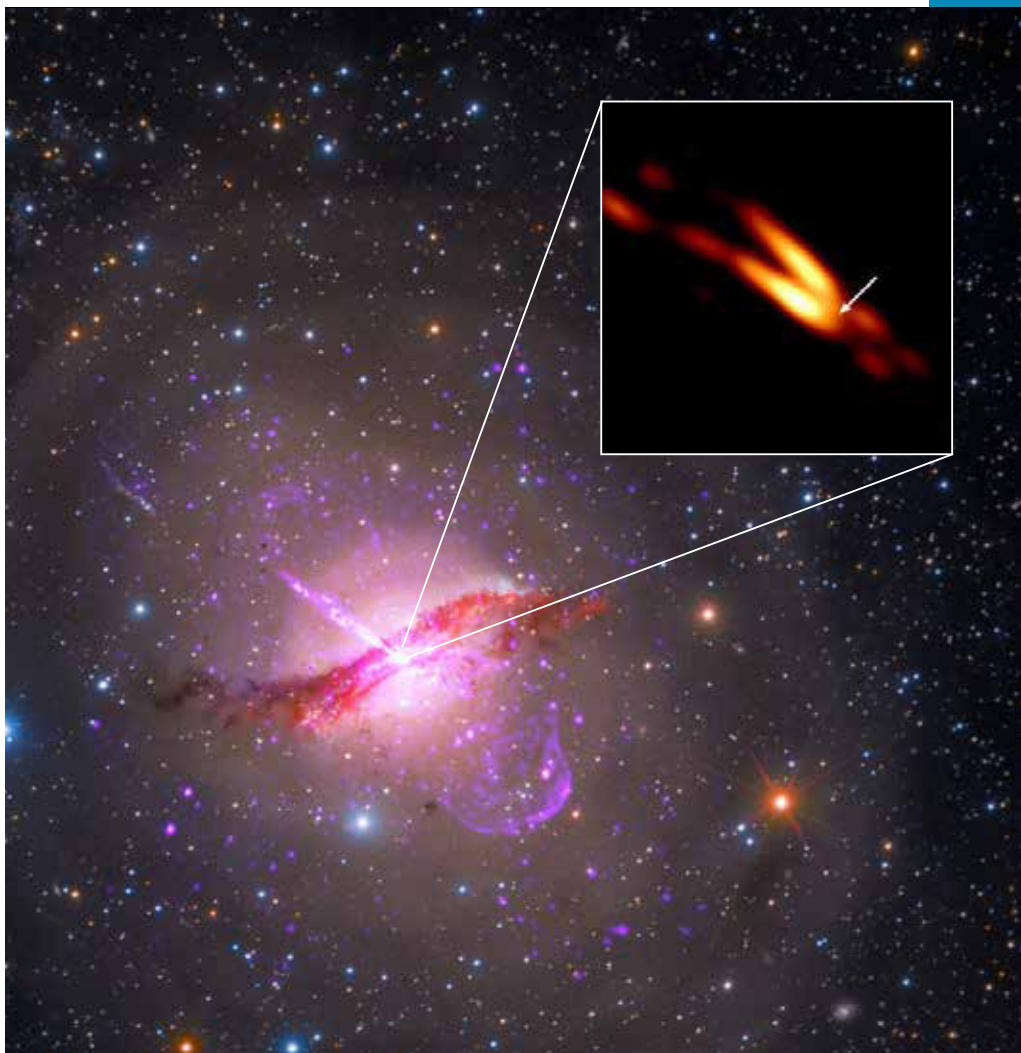
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SNAPSHOT

EVENT HORIZON TELESCOPE ZOOMS IN ON BLACK HOLE JETS

The virtual, globe-spanning Event Horizon Telescope (EHT) recently zoomed in on the black hole at the center of Centaurus A. Shown here in a false-color composite image that combines optical (blue), X-ray (purple), and infrared (red) light, Centaurus A sits 12 million light-years from Earth. EHT's new radio image (inset) shows the galaxy's supermassive black hole (indicated with an arrow) shooting out jets of material. It's the most detailed view of this region to date, showing features less than 1 light-day across. One jet, whose edges glow as two bright streaks split by a dark void at the upper left of the black hole, is moving toward Earth. The second jet, which has much fainter edges and appears to the black hole's lower right, is pointing away from us. Astronomers still aren't completely sure why the jets show this two-pronged look, with a bright sheath surrounding a dark spine. More data — and more stunning, up-close images of black holes — are needed to differentiate between several possible scenarios.

— ALISON KLESMAN

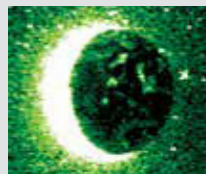


» HOT BYTES



STACCATO SUPERNOVA

Astronomers have discovered the shortest gamma-ray burst from a supernova — GRB 200826A — which lasted just 0.6 seconds, calling into question researchers' current understanding of these bursts.



MARTIAN LIGHTS

The United Arab Emirates' Hope spacecraft captured detailed images of aurorae on Mars' nightside (right). The Red Planet has no global magnetic field, so scientists think these aurorae instead trace magnetized rocks in the crust.



MILLIMETER MOUNTAINS

According to new research, a neutron star's self-gravity squashes any surface deformations to fractions of a millimeter high — even smaller than the centimeter-sized ranges suggested in previous work.

BILLIONAIRES RACE TO SPACE

Richard Branson and Jeff Bezos are the world's newest astronauts. One day, they might make you one, too.



MAIDEN VOYAGE. Crew members Colin Bennett, Beth Moses, Sirisha Bandla, and Richard Branson (center) enjoy a few moments of weightlessness. VIRGIN GALACTIC

» The new space race isn't between global superpowers — it's being hashed out by some of the world's richest billionaires. Richard Branson and Jeff Bezos are the owners of the commercial space operators Virgin Galactic and Blue Origin, respectively. And in July, both men, alongside their crews, successfully launched themselves into space, ushering in a new era for private spaceflight.

BRANSON TAKES FLIGHT

Branson flew first on July 11 after Virgin Galactic moved his flight forward, beating Amazon founder Bezos to space by a little over a week.

The flight was Virgin Galactic's first to carry a full crew: In addition to its two pilots, four mission specialists — one of whom was Branson — were charged with evaluating the safety of the flight and the overall astronaut experience.

On the morning of the flight, VSS *Unity* departed from Spaceport America in New Mexico, strapped to its mothership, VMS *Eve*. After *Unity* was released from an altitude of roughly 46,300 feet (14,100 meters), it soared to a peak altitude of 53.3 miles (85.8 kilometers), reaching space — depending on your definition. Though it did not reach the Kármán line at 62 miles high (100 km) that much of the

world considers the boundary between Earth's atmosphere and space, most U.S. organizations — including NASA, the U.S. Air Force, and the Federal Aviation Administration — recognize 50 miles (80 km) as the target that aspiring astronauts must reach to earn their wings.

For a few minutes, the crew unstrapped themselves from their seats and enjoyed weightlessness. In videos from the flight, Branson and other crew members look out the windows, gazing at the desert landscape of the American Southwest below.

"I have dreamt about this moment since I was a child, but nothing could

have prepared me for the view of Earth from space,” said Branson after the flight.

For the British billionaire, the flight marked the culmination of his efforts to get Virgin Galactic off the ground. Founded by Branson in 2004, the company suffered many delays and two fatal accidents — one in flight and one during an engine test on the ground — while developing its spaceplanes.

On Virgin Galactic’s website, limited numbers of tickets are available for those interested in becoming astronauts — as long as they can pay a whopping \$450,000 per seat.

SPACE SHIPMENT

On July 20, just days after stepping down as Amazon’s CEO, Bezos — along with his brother Mark Bezos, Wally Funk, and Oliver Daemen — reached space inside a capsule carried atop Blue Origin’s New Shepard rocket.

In addition to being the first crewed flight for the private company, the flight also set two astronaut age records. Funk — a former Mercury 13 member who is currently 82 years old — now holds the record as the oldest person to ever fly to space. The Mercury 13 program was a privately funded endeavor in the early 1960s meant to show that women too could be astronauts, but NASA failed to take up the initiative at the time. Thanks to Bezos, Funk finally got her wings. On the other end of the age spectrum, Daemen, 18, is now the world’s youngest astronaut. The young Dutch participant was a late substitution: The original, still anonymous crew member — who secured his seat by bidding a whopping \$28 million in an online auction — opted for a later flight due to a scheduling conflict.

The entire flight took little more than 10 minutes to lift off from West Texas, cross the Kármán line, and safely touch down in the desert. The crew brought a number of aviation artifacts with them, including a piece of canvas from the Wright Brothers’ first powered plane, a bronze medallion made from the first hot-air balloon, and goggles that belonged to Amelia Earhart.



PRIME CREW. Blue Origin’s first human flight crew celebrates with the New Shepard booster. From left: Oliver Daemen, Jeff Bezos, Wally Funk, and Mark Bezos. BLUE ORIGIN

After Blue Origin’s flight, Bezos announced that ticket sales are open for anyone interested in taking the same journey. While the exact price has not been disclosed at the time of writing, those interested should expect a heavy price tag to venture to the stars.

JUST THE BEGINNING

Although both companies outwardly pride themselves on making spaceflight cheaper and more accessible, that message was somewhat undercut by the optics of the historic flights serving as joyrides for two of the world’s richest men. Bezos’ flight in particular ignited an internet firestorm. In post-flight remarks, Bezos thanked his Amazon employees and customers “because you guys paid for all of this” — which only reminded many of the inequities surrounding space travel.

Nevertheless, the successful flights marked a milestone for the commercial space tourism industry. Maybe one day, the boundaries of space will be truly reachable for anyone who dreams of visiting the cosmos. —HAILEY ROSE MCLAUGHLIN

BACK IN BUSINESS

The Hubble Space Telescope suffered a computer memory error June 13 that put the observatory into safe mode. Following weeks of tests, NASA found the issue was a failed power supply. After switching to a backup system, Hubble resumed operations July 17.

SHIVERING MOON

Icequakes may be constantly rippling across the frozen surface of Saturn’s moon Enceladus, caused by tides in the world’s subsurface water ocean. The suggestion comes from models of Antarctic ice shelves, which float atop coastal waters and tend to fracture during falling tides.

SEASONAL RAYS

The magnetar SGR1935+2154 — a highly magnetic, fast-spinning neutron star — fires random bursts of low-energy gamma rays for four months, then goes dormant for three months. This behavior was noticed by researchers last year and repeated as predicted beginning in late June.

EXTRA NEUTRONS

For the first time, astronomers have measured two isotopes of the same element in an exoplanet atmosphere — carbon-12 and its variant with an extra neutron, carbon-13. The exoplanet, gas giant TYC 8998-760-1 b, has more of the latter than expected.

LITHIUM EMPIRE

Classical novae — thermonuclear outbursts from stars siphoning matter from a companion — are thought to produce most of the universe’s lithium. But observations of the 2015 nova V5669 Sgr detected just a few percent of the amount seen in other novae, suggesting these events may not be the sole source of the element. —MARK ZASTROW

Massive white dwarf lives on a knife's edge



NOT EVERY STAR goes out with a bang. In fact, about 97 percent of all stars eventually wither into a sphere of smoldering cinders known as a white dwarf — as will our Sun one day. Following its red giant phase, our star will slough off its outer layers and its core will shrink to about the size of Earth.

The more massive a white dwarf, the smaller its radius — a counterintuitive fact perfectly exemplified by a new discovery from the Zwicky Transient Facility at Caltech's Palomar Observatory. Weighing in at 1.35 times the mass of the Sun, the white dwarf ZTF J1901+1458 is a mere 2,670 miles (4,297 kilometers) across — just a bit wider than the Moon. That makes it both the most massive and the smallest white dwarf ever seen.

At 130 light-years away, ZTF J1901+1458 was formed when a binary pair of white dwarfs merged. That merger left the newly formed white dwarf with a powerful magnetic field about 1 billion times stronger than the Sun's. ZTF J1901+1458 also has a

high rate of spin, revolving once every seven minutes.

Whereas stars rely on the outward pressure created by nuclear burning to keep themselves inflated against the crushing force of gravity, white dwarfs have no internal fuel to burn. Instead, quantum mechanics steps up to fight a white dwarf's self-gravity. The laws of physics state that certain particles, called fermions, cannot exist at the same place at the same time. Inside a white dwarf, electrons (a kind of fermion) are packed so closely together that they create an outward pressure, known as electron degeneracy pressure, in an effort to create some distance.

ZTF J1901+1458 is so densely packed that researchers aren't sure whether this so-called electron degeneracy pressure will be enough to stave off further collapse. If not, gravity will ultimately overcome the electrons' efforts, smashing them through atomic nuclei. There, they will collide with protons to create neutrons, birthing a neutron star. —CAITLYN BUONGIORNO

MOON-SIZED CINDER. The white dwarf ZTF J1901+1458, whose diameter is roughly that of the Moon, appears above Earth's satellite in this artist's concept. GIUSEPPE PARISI

ZHURONG STRETCHES ITS WHEELS

The Mars rover Zhurong continues to cover fresh ground as it explores the Red Planet. Since landing May 14 on Utopia Planitia as part of China's first mission to Mars, it has trekked over half a mile (800 meters), heading south from its landing site. On July 12, it captured this image of its own parachute and backshell, the equipment that helped it descend safely through the martian atmosphere. They had come to rest roughly 1,150 feet (350 m) from the landing site. So far, the rover and its six scientific instruments — including cameras, ground-penetrating radar, and a weather-monitoring station — are operating normally. —M.Z.



THE EVENT HORIZON TELESCOPE

A GLOBAL ARRAY. The Event Horizon Telescope (EHT) is a worldwide array of radio dishes that essentially create a telescope with the same resolving power as a single dish the size of Earth. Thanks to its high resolution, scientists were able to capture the first image of a supermassive black hole's shadow, revealed in 2019. The team

had been working on imaging M87* — the black hole in question — since the array's inception in 2009. The constellation of telescopes ebbed and flowed over that time,

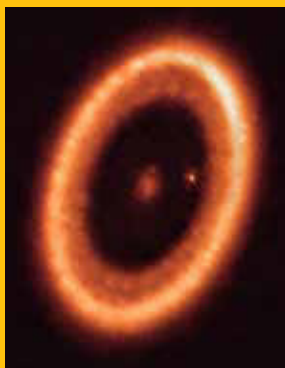
before reaching the eight-telescope team in 2017 that enabled the M87* image known around the world. Since then, the EHT has grown to include an additional three telescopes. —C.B.

FAST FACT

The observations used to image Centaurus A's jets (seen on page 7) were carried out by ALMA, APEX, JCMT, LMT, SPT, SMA, and SMT.

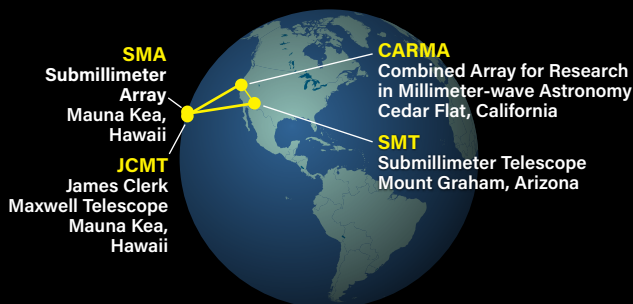
Making a moon

Astronomers have captured the first clear shot of a moon-forming disk around a distant exoplanet. The image at right, taken by the Atacama Large Millimeter/submillimeter Array, shows a wide view of the star PDS 70 (center), as well as the bright ring of material, called a circumstellar disk, surrounding it. Inside the young system, just to the right of the star, is a Jupiter-like exoplanet, PDS 70 c, sporting its own disk — this one called a circumplanetary disk. The researchers say this stellar snapshot serves as the first unambiguous detection of a circumplanetary disk capable of brewing its own moon. They suspect that the amount of material surrounding PDS 70 c is enough to create three Moon-sized satellites. —JAKE PARKS



ALMA (ESO/NAOJ/NRAO)/BENISTY ET AL.

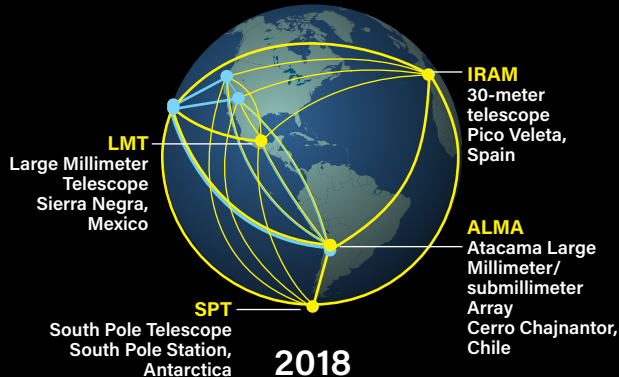
2009–2012



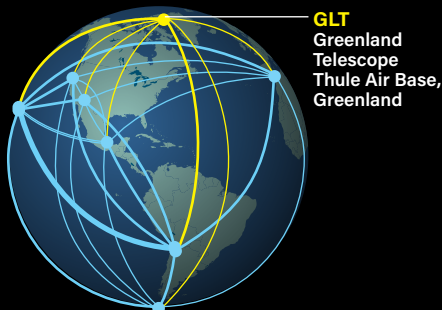
2013



2017



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2021



Space station goes for a spin



DRAMATIC ENTRANCE. The laboratory module Nauka (left) sits parked at the International Space Station after its arrival and docking — and shortly before uncontrollably firing its thrusters. ROSCOSMOS

The International Space Station (ISS) spun out of control July 29 when a newly arrived Russian module unexpectedly began firing its rocket thrusters, sending flight controllers in Moscow and Houston scrambling to recover the station. The episode was one of the most serious in the ISS's 22-year history, resulting in a 47-minute period during which the station lost control of its attitude (or orientation), even as other thrusters fired off in an effort to stabilize the orbiting outpost.

The incident began at 12:34 P.M. EDT when the station's attitude began drifting, about three hours after the Nauka laboratory module had docked

at the ISS. The astronauts reported that they could see Nauka firing its thrusters, though it had not been commanded to do so.

At 12:42 P.M. EDT, as the station performed a backflip, mission controllers declared a loss of attitude control. Mission Control Center in Moscow instructed the station's Russian-built Service Module to fire its thrusters to counteract Nauka's stuck thrusters.

However, the Service Module did not have enough thrust or leverage to overpower Nauka. This prompted controllers to command a Russian Progress cargo craft docked at a different port to fire its thrusters. Eventually, Nauka's thrusters stopped firing — perhaps exhausting their propellant — and at 1:29 P.M. EDT, attitude control was restored.

According to NASA Flight Director Zebulon Scoville, who was one of two flight directors overseeing Mission Control during the incident, the ISS completed more than one full rotation, with its rate of pitch peaking at roughly half a degree per second.

In a press briefing later that afternoon, Kathy Lueders, head of NASA's human spaceflight program, called it "a pretty exciting hour" and gave credit to the mission team's preparedness and contingency planning.

NASA said the astronauts were never in danger — but Scoville tweeted that he'd never "been so happy to see all solar arrays [and] radiators still attached" to the ISS. "Today had a little more danger than your typical orbit-punching Thursday."

Russian space agency Roscosmos is leading an investigation into the incident. In a July 30 statement, it said the errant firing was due to a computer glitch. —M.Z.



PAUL K. BYRNE AND SEAN C. SOLOMON

CRACKING VENUS' CRUST

THIS INTRIGUINGLY ALIEN, false-color radar view of Venus captures a nearly 700-mile-wide (1,100 kilometers) stretch of Lavinia Planitia, a lowland region on our sister world. But it's more than just a pretty picture. Lavinia Planitia, as with other such regions on Venus, is a patchwork of crustal blocks called *campi* (purple in this image) that are loosely stitched together by beltlike tectonic structures (yellow) and move laterally relative to each other, rubbing up against one another. Although these *campi* can be as large as Alaska and are similar to some crustal blocks on Earth, Venus does not sport active global plate tectonics like our planet does. Instead, a new study published June 21 in the *Proceedings of the National Academy of Sciences* found supporting evidence that the crust of Venus is deformed by convection within the planet's viscous interior. Their simulations showed this stresses the thinner lowland crust where *campi* are found, causing them to subtly shift. —J.P.

1,137 The diameter of Mars' molten core, in miles (1,830 km), as measured by NASA's InSight lander.

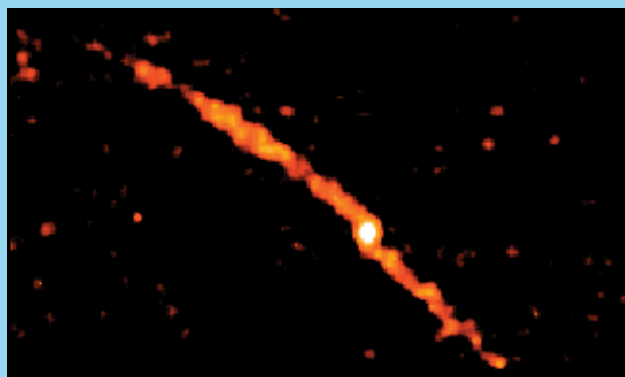
CLUSTER SPORTS ABUNDANCE OF BLACK HOLES

The Milky Way can be pretty disruptive to the dwarf galaxies and globular clusters that orbit it. Our galaxy's gravity can pull and stretch these objects, creating stellar streams that arc along their orbits.

To better understand how these streams evolve, researchers looked to Palomar 5. Best known for its spectacular twin streams of stars, Palomar 5 is also one of the sparsest globular star clusters around the Milky Way. Both features are likely caused by a combination of the Milky Way's gravity and an overabundance of stellar-mass black holes hidden within the cluster, according to new research published July 5 in *Nature Astronomy*.

"The number of black holes is roughly three times larger than expected from the number of stars in the cluster," said lead author Mark Gieles of the Institute of Cosmos Sciences of the University of Barcelona in a press release. "It means that more than 20 percent of the total cluster mass is made up of black holes."

By simulating the cluster's evolution, the team found that Palomar 5 began with a more typical mixture of stars and black holes, but stars were lost at a higher rate than black holes. This ultimately led to an imbalance that further contributed to the loss of stars, as interactions with the black holes



STELLAR STREAMING. Palomar 5 is a globular cluster in the process of being torn apart by the Milky Way. One of the fluffiest clusters orbiting our galaxy, Palomar 5 has about three black holes for every star.

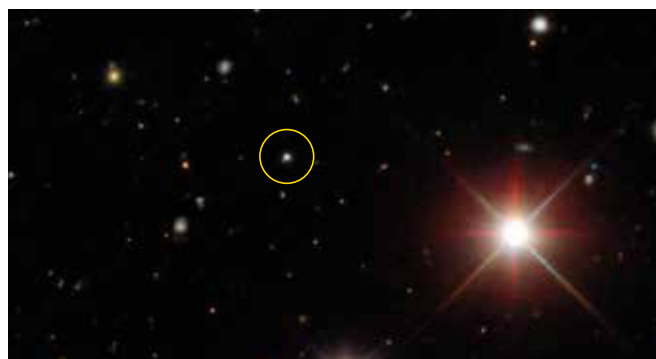
sent stars careening from the cluster. The researchers estimate that by the time the cluster is completely torn apart — approximately 1 billion years from now — Palomar 5 will only host black holes, with no stars left at all. —C.B.

Giant comet found in dark energy data

Astronomers Pedro Bernardinelli and Gary Bernstein of the University of Pennsylvania have made a massive discovery — literally. They've spotted the largest comet found in modern times, and it's headed for a close encounter with the Sun in 2031.

The pair made the discovery by searching through six years of images taken for the Dark Energy Survey by the 570-megapixel Dark Energy Camera (DECam) on the 4-meter Victor M. Blanco Telescope in Chile. While snapping pics of distant galaxies from 2013 to 2019, DECam also spotted interloping solar system objects, including the comet now called C/2014 UN₂₇₁ (Bernardinelli-Bernstein).

Comet Bernardinelli-Bernstein is some 60 to 120 miles (100 to 200 kilometers) across. It is an estimated



TARGET ACQUIRED. Astronomers discovered the massive Comet Bernardinelli-Bernstein (circled in this composite image) in 32 of 80,000 photos taken by the Dark Energy Camera. DARK ENERGY SURVEY/DOE/FNAL/DECam/CTIO/NOIRLAB/NSF/AURA/P. BERNARDINELLI & G. BERNSTEIN (UPENN)/DESI LEGACY IMAGING SURVEYS. ACKNOWLEDGMENTS: T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF'S NOIRLAB), M. ZAMANI (NSF'S NOIRLAB) & J. MILLER (NSF'S NOIRLAB)

1,000 times more massive than the average comet. Bernardinelli-Bernstein is now the largest known member of the Oort Cloud — a spherical shell of icy, rocky remnants from the solar system's early years.

Astronomers estimate this comet began its journey some 40,000 astronomical units away. (One AU is the average

Earth-Sun distance.) That's about 15 percent of the distance to the Sun's nearest stellar neighbor, Proxima Centauri.

As of early August, the comet had reached the distance of Uranus' orbit, nearly 20 AU from the Sun. By then, its surface had warmed, causing it to develop a coma — a cloud of dust and gas that surrounds a comet as surface

ices boil off. This coma officially clinches Bernardinelli-Bernstein as a comet.

Despite its heft, there's nothing to worry about — Bernardinelli-Bernstein will steer far clear of Earth. Its 2031 perihelion (the closest point in its orbit to the Sun) will bring it only 11 AU from our star, a little farther out than Saturn. At that distance, the comet probably won't grow very bright and will still require a large amateur telescope to spot.

This is hopefully just the first discovery of many, as we spot more large objects that were flung to the far reaches of the solar system when the outer planets jockeyed for position billions of years ago. Astronomers will be eagerly following this comet's progress, as well as searching for similar objects that can reveal more about our early solar system. —A.K.

Alien life

Are we searching for E.T. the wrong way?



A typical appendix page from the author's book, *The Grand Biocentric Design*, argues that the key cosmological role of consciousness can be demonstrated through physics and math. BOB BERMAN



BY BOB BERMAN
Bob's recent book, *Earth-Shattering* (Little, Brown and Company, 2019), explores the greatest cataclysms that have shaken the universe.



Just briefly, let's be unafraid to question cosmology's most basic assumptions.

Let's start with the Drake equation, which estimates the number of communicating alien intelligences in the galaxy. Its fame has grown, since its 1961 creation, to virtually rival Einstein's $E=mc^2$. Frank Drake's brainchild became one of the key tenets of astrobiology and still shapes efforts to search for alien life, including the James Webb Space Telescope's plan to characterize habitable exoplanets. Recently, physicists at Britain's University of Nottingham published a new analysis of this formula, concluding there are likely 36 alien civilizations in the Milky Way currently emitting signals we might be able to detect.

It all jibes with the standard cosmological model, which depicts the universe as a matter-and-energy-based entity that accomplishes cool things through random activity. Ever since its sudden appearance as a hyperdense marble-sized ball that bewilderingly popped out of nothingness, the cosmos, employing nature's four forces, has created conscious life on at least one world. Astronomers' biggest current quest is to locate other such worlds where this happened.

I may be the only one who hates all this. Starting with the Drake thing: That equation certainly tidied up the messy alien puzzle by clothing it in a respectable formula. But if you dislike hypotheticals, you may be wary of Drake's thinly veiled guesses. For example, many intelligent life-forms, such as orangutans and dolphins, show little interest in actively contacting other species. So, how many alien intelligences would actually build transmitters and broadcast radio signals in an effort to

communicate? Drake guessed it was one out of every 100.

There's nothing wrong with guesswork. So there's also no harm if we suggest a very different model for alien life in the universe, closer to the beliefs of Werner Heisenberg and his genius colleagues who developed quantum mechanics a century ago. With undisguised amazement, they found that human consciousness altered the results of their experiments. Consider the double slit, which shows that the forms taken by fundamental particles — meaning whether electrons, photons, and the like act as waves or discrete particles, and even how and when they appear — depends on knowledge in the human mind rather than the arrangement of the apparatus.

Erwin Schrödinger believed that consciousness is fundamental to the universe. He said in a 1931 interview, "Although I think that life may be the result of an accident, I do not think that of consciousness. Consciousness cannot be accounted for in physical terms. For consciousness is absolutely fundamental. It cannot be accounted for in terms of anything else."

With those ideas in mind, this year, medical doctor Robert Lanza, theoretical physicist Matej Pavšič, and I published *The Grand Biocentric Design* (BenBella Books, 2021), which builds upon the work of those quantum originators. The resulting science, also published in May in the *Journal of Cosmology and Astroparticle Physics*, supports a very different universe than the one Drake's equation describes. If true, the current quest for alien life may need a bit of expanding.

How? Let's assume those quantum originators were right and consciousness is indeed fundamental, meaning it doesn't come and go. In that case, the cosmos might be defined not as an insentient matter/energy object but as an eternal self-awareness. And this can actually be mathematically demonstrated through experiments such as that double slit, in which the instantaneous metamorphoses of objects (electrons) have no other explanation except a correlation between human awareness and the physical world.

The quest for alien life may need a bit of expanding.

What if, here on Earth and perhaps elsewhere, brains arise with an architecture that nature specifically designed to capture, filter, and cognize consciousness? This suggests that while the brain perceives consciousness, it's not its originator. Indeed, no one's ever explained how awareness can arise from matter, including brain tissue.

This is what suggests there may be a key aspect we're overlooking in the search for alien life. We currently picture planets as blank slates, devoid of life and consciousness. We act as if the burden is on astrobiologists to show how life can arise from these primordial soup bowls. But to those who see the cosmos as fundamentally consciousness-based, those quests are pointless. They're asking the wrong questions. Instead, by assuming consciousness will be encountered in many places, we can begin exploring several steps ahead in the game. ▀



BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT www.Astronomy.com/Berman

A crescent corona

Earth's atmosphere can create a gorgeous glow around a crescent Sun or Moon.



In this shot of a "crescent corona," the aureole is visible as a largely elliptical glow with a distinct bay or notch that mimics the appearance of the crescent Sun. The photographer took the 1/60-second exposure at ISO 200 with a Pentax K-3 II camera and 300 mm lens at f/5.6, equipped with a Hoya Pro ND100000 (5.0) solar filter. DANIEL W.E. GREEN



Don't be fooled by the title of this article! It does concern a recent solar eclipse, but not a total one. The Sun's corona — the crown of plasma that makes up its outermost layer — was not even visible.

Still, an atmospheric corona was. This visual phenomenon seen around the Sun is produced by small water droplets that diffract sunlight or moonlight.

The feature appeared during the June 10, 2021, solar eclipse, which was partial over New England. On that morning, Harvard University astronomer Dan Green traveled to Duxbury Beach, 35 miles (56 kilometers) southeast of Boston, to view and photograph the spectacle over the Atlantic Ocean. The Sun was due to rise out of the sea with the Moon already covering it.

"When we arrived at the beach a half-hour before sunrise," Green said, "we saw that there was a [distant] thick cloud layer (all high-altitude clouds) low over the ocean, and unfortunately they continued to increase as time progressed. I tried but was unable to image the Sun around sunrise (5:08 A.M. EDT) due to the thickness of the clouds."

Because maximum eclipse (73 percent) was set to occur just 30 minutes after sunrise, with the Sun only 3.5° above the horizon, the situation was uncertain. But about 15 minutes after sunrise, Green reported, "the Sun gradually broke through openings in the clouds" as it rose. He captured the photo shown above near the time of maximum eclipse "through thin, diffuse" clouds.

While it was disappointing to have clouds throughout the event, Green nonetheless captured a beautiful aureole — the corona in its simplest form — around the

solar crescent. Note the aureole's aqua disk, which fades to reddish-brown toward the edge.

Strictly speaking, in a full corona, the aureole is surrounded by concentric rings, which were absent here. Nevertheless, the event shows how less-than-perfect eclipse conditions can create an uncommon display of ethereal beauty when the Sun, Moon, and Earth's atmosphere work together.

Casual observers most commonly observe aureole around the Full Moon, when the feature is brightest and appears circular. But in this case, the aureole appeared largely elliptical around the crescent Sun. The most fascinating feature Green captured is a distinct bay or notch in the aureole on the side of the occulting Moon, giving the aureole a slight crescent shape.

This feature is subtle and difficult to capture — especially visually. It is hardly ever reported, perhaps because seeing it requires spending time studying the phenomenon (with direct and averted vision) to make out the notch. The aureole is mirroring the fact that the crescent Sun is longer on the north-south axis and shorter on the east-west axis. Note, too, that the aureole is centered not on the solar disk but on the illuminating source: the solar crescent.

The intensity and size of an aureole depends on the brightness of the illuminating source and the size of the atmospheric particles (whether they be water droplets or needlelike ice crystals). As a general rule, the brighter the illuminating source, the more pronounced the aureole. Also, the smaller the particles, the larger the aureole, and the more color and definition it possesses. This also explains why the edge of the aureole appears red, because aureoles created from long-wavelength red light are larger than those created from short-wavelength blue light.

The aureole in Green's image is very small — about 20' in radius. The smallest on record is about 10', indicating that the particles in the cloud creating it were quite large.

Of course, we don't have to wait for an eclipse to see the crescent corona, as it can also occur with any waxing or waning crescent Moon. So why not challenge yourself to spot your own crescent corona? As always, send your thoughts and observations of curious phenomena to sjomeara31@gmail.com. ☿



A waxing crescent Moon and crescent corona, as seen from Maun, Botswana. STEPHEN JAMES O'MEARA



BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.



BROWSE THE "SECRET SKY" ARCHIVE AT
www.Astronomy.com/OMeara

FIFTY YEARS AGO THIS NOVEMBER, three spacecraft were bearing down on Mars in a frantic race to become the first mission to orbit it.

They were the survivors of a fleet of five. Of that group, two were NASA efforts: Mariner 8 and Mariner 9, jointly known as the Mariner Mars 71 Project. The other three were Soviet: M71-S (S for “Sputnik”), Mars 2, and Mars 3.

All five spacecraft were designed to orbit the Red Planet, and Mars 2 and Mars 3 were also designed to deploy landers that would attempt the first robotic surface explorations of that world. After having lost the race to put a man on the

Moon two years earlier, the Soviets were determined to beat the U.S. to the surface of Mars, even if only with robotic missions.

But when the dust settled, there was one standout performer: Mariner 9. That spacecraft is remembered among the most successful interplanetary missions of all time. Its systematic mapping of the martian surface in all its grandeur not only paved the way for future generations of robotic explorers, it forever changed our understanding of our neighboring planet.

Before probes visited Mars, the world



50 YEARS ON MARS

The current international fleet of explorers follows the path blazed by NASA's pioneering Mariner 9 mission.

BY JIM BELL AND WILLIAM SHEEHAN

had seemed Earth-like in so many ways. Then, when earlier Mariner missions made flybys of the Red Planet in the 1960s, their limited images triggered something of a disappointment: a barren world covered in craters like the Moon, albeit with a thin atmosphere. But Mariner 9 showed Mars to be a world unto itself.

Meeting Mars

The five missions that launched toward Mars in May 1971 set a record for a

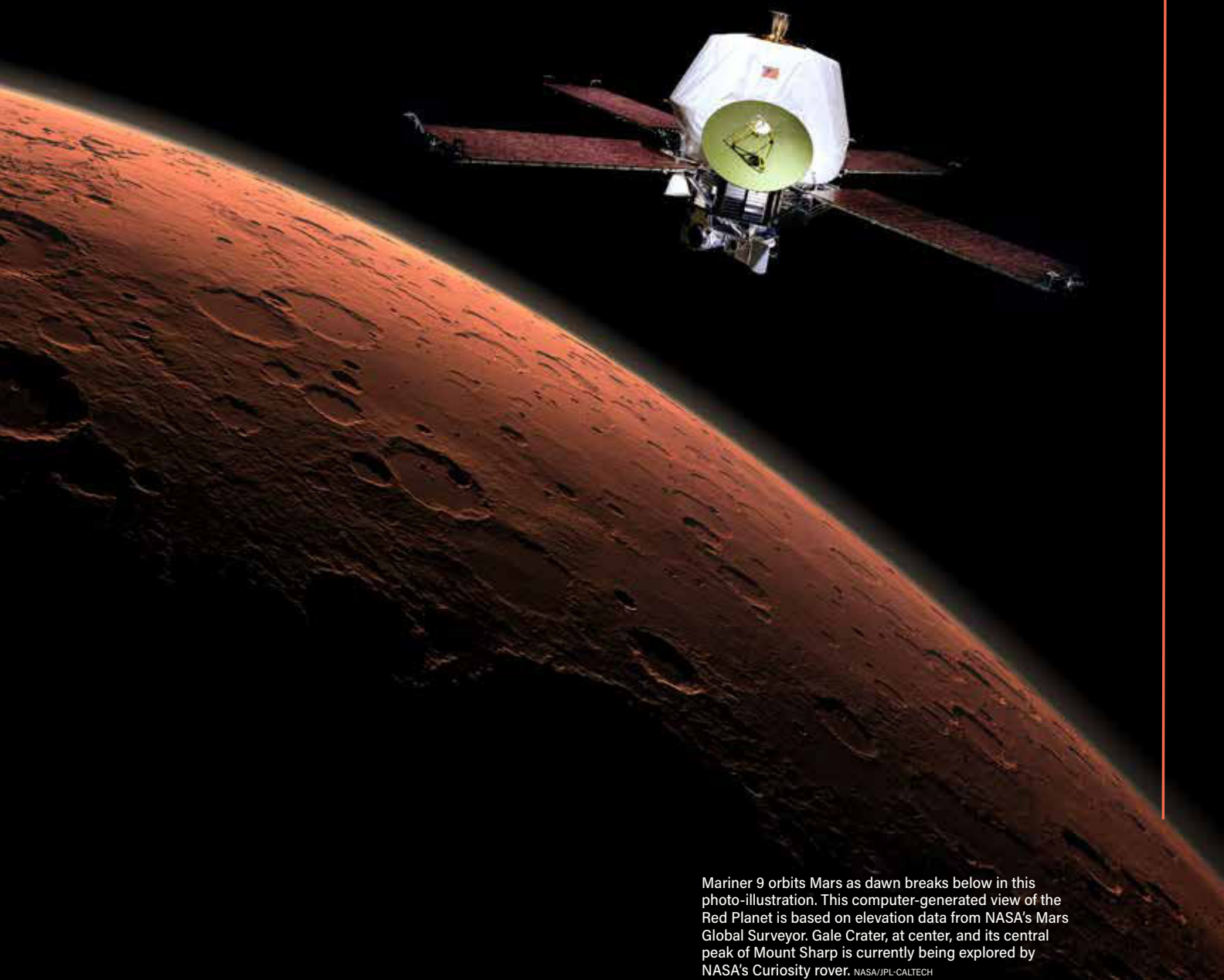
single year that remains unbeaten to this day.

The campaigns of both the U.S. and USSR got off to an inauspicious start. Mariner 8 was the first to launch, on May 9. But the mission quickly ended in disaster as the Atlas rocket's Centaur upper stage tumbled out of control just five minutes after launch, dooming the spacecraft to a watery grave north of Puerto Rico.

Just two days later, the M71-S mission also met an early end. After a

Proton rocket put the spacecraft into a parking orbit around Earth, the upper stage booster engine failed to fire and the spacecraft fell back to Earth two days later.

The ambitions of both nations were salvaged by their insurance policy of launching multiple spacecraft to the same target — a policy that has largely been abandoned in recent decades due to budget constraints. The launches of Mars 2 and Mars 3 on May 19 and 28, respectively, were successful, as was the



Mariner 9 orbits Mars as dawn breaks below in this photo-illustration. This computer-generated view of the Red Planet is based on elevation data from NASA's Mars Global Surveyor. Gale Crater, at center, and its central peak of Mount Sharp is currently being explored by NASA's Curiosity rover. NASA/JPL-CALTECH

launch of Mariner 9 on May 30. The race was on to become the first spacecraft to orbit the Red Planet.

Even though it was the last to lift off, the vagaries of interplanetary trajectories meant that Mariner 9 had the potential to reach Mars orbit first (although M71-S could have beaten Mariner 9 if its launch had succeeded). Indeed, on the evening of Nov. 13 EST, after a 167-day flight, a 15-minute burn of Mariner 9's main engine allowed Mars to capture the spacecraft into orbit.

Only 13 and 18 days later, respectively, Mars 2 and Mars 3 also entered Mars orbit shortly after releasing their landers. The Mars 2 lander crashed into Mars — its descent system failed sometime between atmospheric entry, deploying its parachute, and firing its retrorockets to slow down.

The Mars 3 lander performed better, but space historians continue to debate its ultimate fate even today. The USSR claims that it achieved the first soft landing on the martian surface. But communications with the lander were lost around 20 seconds after landing, and no useful data were downlinked to Earth. Even if it did land safely, it was a pyrrhic victory.

Still, by the end of 1971, humanity had three functional orbiters around Mars. Scientists around the world were eager to build upon the initial glimpses of that world provided by the earlier Mariner 4, 6, and 7 flyby missions. But Mars had other plans.

Into the maelstrom

One reason for the flurry of martian launch attempts in 1971 is because Earth passed extremely close to Mars during that year's opposition — just 0.38 astronomical unit (AU), where 1 AU is the average distance between Earth and the Sun. This allowed for the shortest possible travel times between the two planets.

That favorable August opposition also meant that professional and amateur astronomers back on Earth were getting outstanding views of the 20"-to 25"-wide Red Planet as the three orbiters approached it throughout the summer and early fall. What they saw

in late September was stunning: Mars was rapidly being engulfed in one of its famous and unpredictable global dust storms. Within three weeks, the entire planet was totally obscured.

All three orbiters and the two ill-fated Soviet landers had flown right into a maelstrom, the conditions of which were essentially unknown. When NASA mission controllers at the Jet Propulsion Laboratory (JPL) in Pasadena switched on Mariner 9's cameras in early November, they saw a bland planetary disk, featureless except for the bright southern polar cap and four mysterious dark spots near the equator.

Despite being so close to the planet, all three orbiters had to wait for the

dust to clear to view the martian surface. Mars 2 was in an 18-hour elliptical orbit but had been programmed to take most of its data during close approaches. Mars 3 had even less-frequent opportunities for up-close observations: During orbital insertion, its engine had shut down early, leaving it in a highly elliptical orbit lasting nearly 13 days.

Nevertheless, during their three-month primary operations periods, both missions managed to return significant amounts of data about the planet's temperature, gravity, and magnetic fields — plus a total of 60 dust-obscured images. However, hardly anyone now remembers their contributions to Mars science.

Star performer

On the other hand, Mariner 9 enjoyed spectacular success, thanks to its longevity — enabling it to wait out the

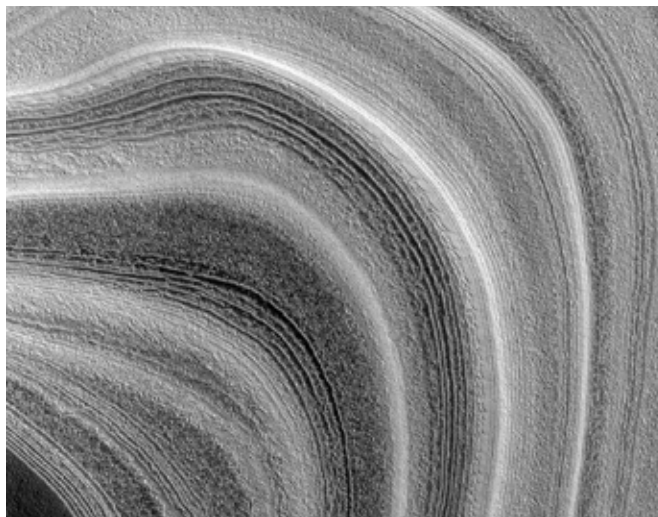


LEFT: When Mariner 9 entered orbit around Mars on Nov. 14, 1971, its view of the planet's surface was obscured by dust. Only the southern polar cap and four mysterious dark spots were visible.

NASA/JPL-CALTECH/TED STRYK

BELOW: Mariner 9 discovered strange grooves lining the surface of Phobos, seen here in an image from NASA's Mars Reconnaissance Orbiter, which has been stationed at the planet since 2006. The grooves may have been carved by boulders that rolled along the moon's surface and were perhaps produced by impacts with other objects. NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA





LEFT: Mariner 9 revealed that the northern and southern (pictured) polar caps partake in a dramatic interplay with Mars' atmosphere. While the caps themselves are mostly water ice, each winter, when one pole is plunged into darkness, as much as one-third of Mars' entire atmosphere freezes and coats the cap in a form of carbon dioxide ice, or dry ice. NASA/JPL-CALTECH/TED STRYK

ABOVE: In the spring, the dry ice sublimates away. Over millennia, this repeated process has left behind a series of deposits that resemble tree rings, as imaged here by NASA's Mars Reconnaissance Orbiter. Like tree rings, these polar-layered deposits capture data about the history of the martian climate. NASA/JPL/UAIRIZONA

storm — and adaptability. Following Mariner 8's demise, Mariner 9's mission profile was reprogrammed so that it could accomplish almost all the objectives originally planned for both spacecraft. And while the spacecraft bided its time, Mariner 9 mission scientists used an impressive collection of then-cutting-edge ultraviolet and infrared spectrometers to learn as much as possible about the dust storm itself.

In the pre-Mariner era, the importance of the planet's largest dust storms

on record was raging. It was the first truly global storm observed — even the polar caps were briefly hidden from view for a time.

Though inconvenient at first, the storm of 1971 became a prime scientific opportunity, allowing scientists to investigate how these events influence Mars' atmosphere and surface. And after all, monitoring the Red Planet's atmosphere over time had been Mariner 9's primary goal.

One of the mission's more puzzling

large volcanic eruptions — to develop models that explained how dust suspended in a planet's atmosphere cool the surface while simultaneously warming the upper atmosphere.

Sagan and his colleagues eventually used these models to predict that a global nuclear war between the superpowers on Earth would result in a nuclear winter — a massive cooling of our planet's surface. Clearly, understanding our neighboring planets like Mars can prove to be more than just academic.

All three orbiters and the two ill-fated Soviet landers had flown right into a maelstrom, the conditions of which were essentially unknown.

had been overlooked. Earthbound astronomers had often observed local and regional obscurations known as yellow clouds, but thought that global events were extremely rare. In 1956, one such dust storm encircled the planet; as the first in the Kodachrome film era of modern color photography, it made a significant impression on the professional and amateur planetary astronomy community. But Mariner 9 visited just as the greatest dust storm

discoveries was that the planet's surface temperature was significantly lower when the atmosphere was dustier. Among those who pored over these measurements were Mariner 9 team members Carl Sagan and his first graduate student Jim Pollack, an expert in planetary atmospheres. They and others would combine Mariner 9 data with surface data gathered a few years later by the Viking landers — as well as data on Earth's surface temperatures after

Mars emerges

The dust finally began to clear from the martian atmosphere in early 1972, allowing Mariner 9 to begin systematically mapping the entire surface of Mars. Planetary scientist and space artist William K. Hartmann, then a young member of the Mariner 9 science team, recalled how shortly after the spacecraft arrived, everything was completely obscured by dust except for the four mysterious dark spots near the equator:

"One day, Carl Sagan came running down to the science team room from the upstairs 'computer' room that had



ABOVE: Olympus Mons stands 82,000 feet (25 km) above the surrounding terrain and is roughly 370 miles (600 km) wide. The entirety of the shield volcano is visible in this Mariner 9 colorized mosaic taken over two orbits on March 8, 1972. NASA/JPL-CALTECH/TED STRYK

RIGHT: This oblique view of Olympus Mons was created with topographic data and imagery from NASA's Mars Global Surveyor, which observed the Red Planet from 1997 to 2006. NASA/MOLA



been receiving images from the Goldstone tracking antenna, waving a Polaroid photo of the TV screen (the mode of initial transfer of Mariner 9 images to the science team!). The photo revealed a pretty clear volcanic caldera in a summit protruding from the clouds. That was the day that everyone realized the dark spots were enormous shield volcanoes.”

Shield volcanoes are common geologic features on Earth; among the most famous are the Hawaiian volcanoes Mauna Kea and Mauna Loa. The volcanic structures discovered on Mars, however, make even Earth's largest examples seem puny by comparison. The largest martian volcano, comparable in area to the state of Arizona but towering some 82,000 feet (25 kilometers) above the nearby plains, was named Olympus Mons because it coincided with the perennially cloudy region that 19th century Mars observer Giovanni Schiaparelli had dubbed Nix

Olympica, the Snows of Olympus. The three other dusky spots corresponded to the shield volcanoes now known as Ascræus Mons, Pavonis Mons, and Arsia Mons, from north to south.

The martian geologic wonders that Mariner 9 revealed did not cease there. An oblique photo taken while the dust was still clearing provided the first dramatic glimpse of an enormous and still partially dust-filled canyon network extending along the equator for 2,500 miles (4,000 km), roughly the distance between New York and Los Angeles. This sprawling system of vast gorges was named Valles Marineris in honor of the mission and team that first discovered it.

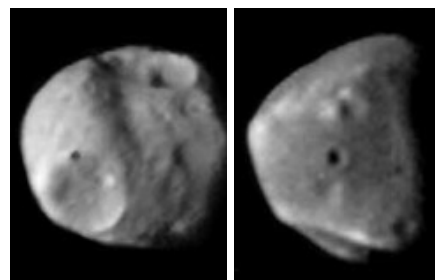
Among the most surprising of Mariner 9's many discoveries — especially after the discouraging results from earlier Mariner flybys that showed a barren Moon-like landscape — was a variety of dry river valleys on Mars. Some of these are now

referred to as outflow channels and appear to emerge from jumbled areas of chaotic terrain. Their closest Earth analogues are deep channels like those found in the Channeled Scablands in eastern Washington state, which were formed by cataclysmic floods during the last glacial maximum some 20,000 years ago. Other dry river valleys resemble typical slower-forming river-carved valleys and distributary valley networks on Earth.

Most were found in the southern highlands of Mars, which contains ancient, heavily cratered terrain. This suggested that sometime in the distant past, liquid water flowed on the planet's surface. Since the surface of Mars — with its freezing temperatures and low atmospheric pressure — cannot support liquid water today, there must have been a time in the ancient past when the planet was warmer and wetter. This period was perhaps 2 billion to 4 billion years ago, with the exact dates and duration still debated by scientists. In retrospect, we can say that Mariner 9 enabled the discovery of what is likely to be one of the most stark and impressive examples of climate change in the history of our solar system.

A new view of Mars

As Mars' surface was mapped over the course of the mission, the Mariner 9 team visualized its progress by pasting individual spacecraft images onto a huge globe in Theodore von Kármán Auditorium at JPL. Ultimately, more



Mariner 9 snapped these images of Mars' small moons — Phobos (left) and Deimos (right) — which are thought to be captured asteroids.

NASA/JPL-CALTECH/PHIL STOOKE

than 7,000 images covering 85 percent of the planet were pasted to that globe.

As the mission continued, it became clear that the earlier Mariner flyby missions had simply been unlucky: Their close-range images had only shown the heavily cratered old plains of the southern hemisphere. Due to this unintended selection bias, they had missed many of Mars' most intriguing features. Instead of returning these rather uninteresting lunarlike landscapes, Mariner 9 revealed a revolutionary new Mars with a rich geologic, atmospheric, climatic, and — potentially — even biologic history.

Among other things, Mariner 9 data also retired the earlier notion that Mars' polar caps were mere deposits of frozen carbon dioxide (dry ice) by showing that when the dry ice sublimates off during martian summer, a kernel of water ice remains. This revelation opened up our understanding of the polar caps' dynamic water- and dry-ice cycles, whose variations over time are recorded in the complex polar-layered deposits first recognized by Mariner 9.

And, in a real tour de force, Mariner 9 photographed Mars' two diminutive moons, Phobos and

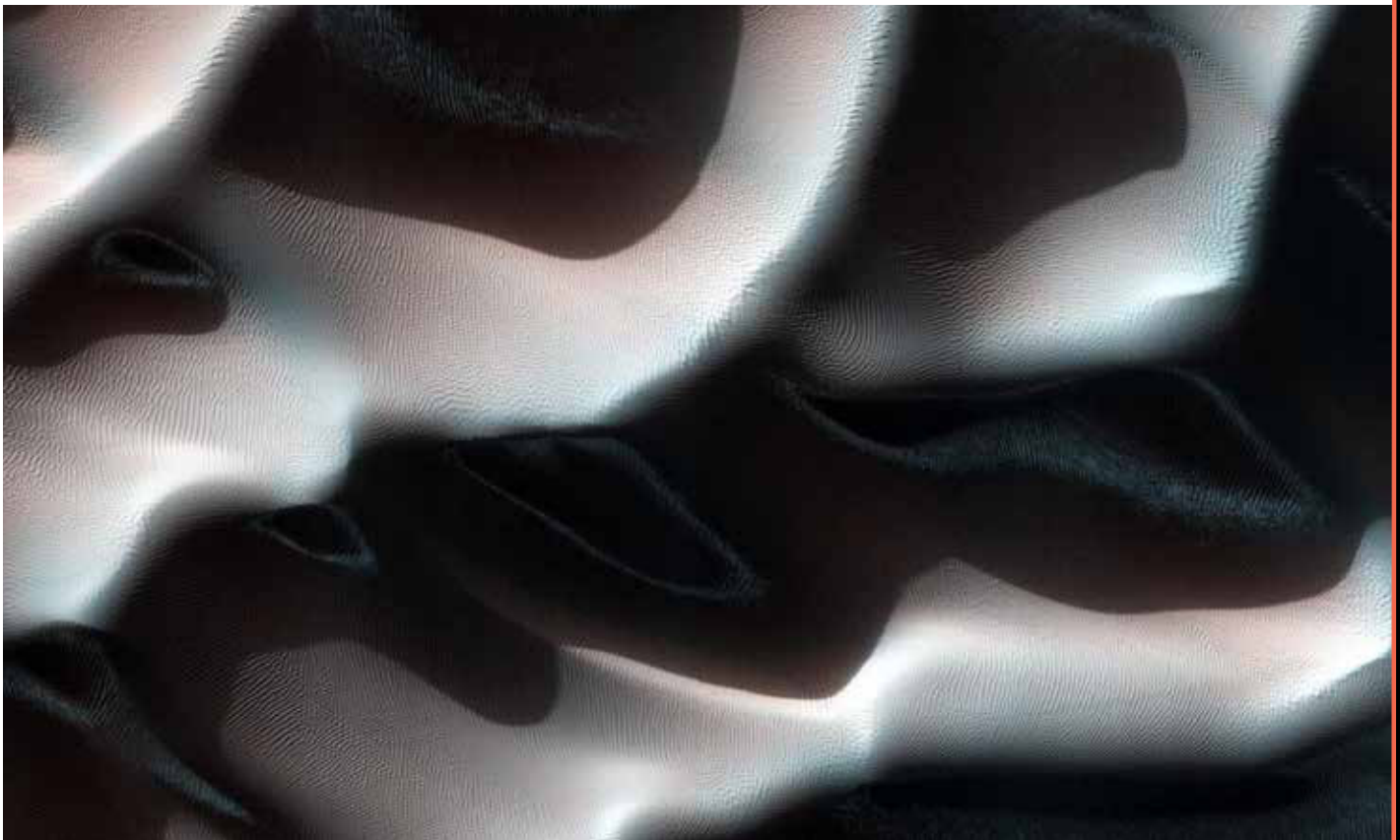


A technician pastes images of the martian surface returned by Mariner 9 onto two globes at the Jet Propulsion Laboratory in Pasadena. WILLIAM K. HARTMANN

Deimos. Discovered only in 1877, they had appeared as mere starlike points in even the largest telescopes on Earth. Mariner 9 captured them at close range, revealing surfaces pocked with craters and, in the case of Phobos, the first hints of strange grooves. (These grooves would later be imaged at much higher resolution by the Viking orbiters, but their origins are still mysterious.)

With so many achievements, it is difficult to choose any one as the most enduring of Mariner 9's legacies. But a case could be made for its reinvigoration of the nascent field of astrobiology. The buzz created by the discovery of

Dramatic shadows fall across a martian dune field in this image from NASA's Mars Reconnaissance Orbiter. In the shadows, deep in the troughs of the dunes, traces of frost are visible. NASA/JPL-CALTECH/UNIV. OF ARIZONA





The Sun dips behind the hills around Gale Crater, as captured by NASA's Curiosity rover on April 15, 2015, at the end of its 956th sol, or martian day. NASA/JPL-CALTECH/MSSS/TEXAS A&M UNIV.

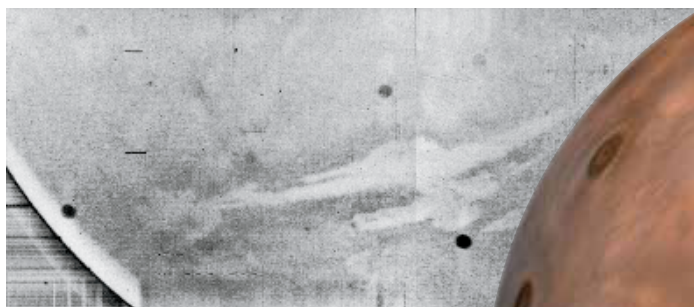
the planet's evolving surface and history of climate change dramatically restored Mars back from a moribund analogue of the Moon (with a thin atmosphere) to its position as a leading candidate for a potentially once-habitable world in our solar system.

A lasting presence

That excitement helped planetary scientists and NASA to promote and create a pair of new missions: Viking 1 and 2. Each mission consisted of an orbiter and a lander. The orbiters mapped the surface and atmosphere in more detail, and the landers performed the first scientifically meaningful surface missions

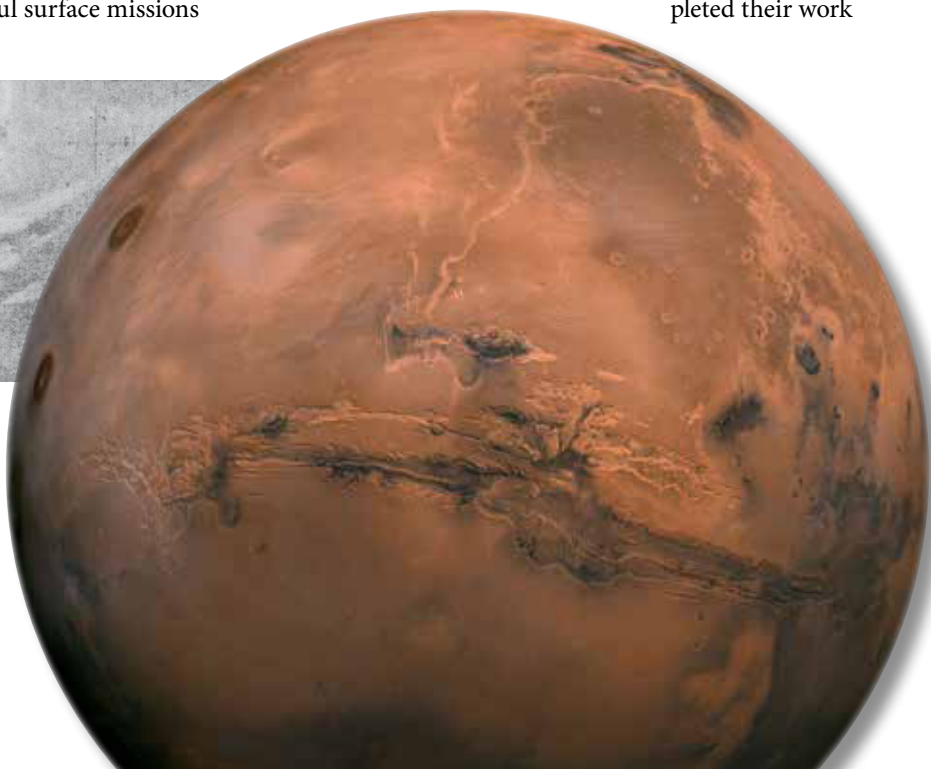
on Mars. They owed their success to Mariner 9 in a very real sense, as their landing sites were selected based on Mariner 9 mapping.

Mariner 9, and to a lesser extent Mars 2 and Mars 3, also initiated what has now become a long-term robotic presence at the Red Planet. After those pioneering missions completed their work



Above: The immense canyon system that would be named Valles Marineris first revealed itself to Mariner 9 scientists in images that showed its lower reaches still partially filled with dust. NASA/JPL

Right: The vast scar of Valles Marineris — one of the largest canyon networks in the solar system — stretches over 2,500 miles (4,000 km), from Noctis Labyrinthus in the west to chaotic terrain carved by outflow channels to the east. This mosaic of 102 images was taken by Viking 1's orbiter, which operated in Mars orbit from 1976 to 1980. NASA/JPL-CALTECH





in 1971 and 1972, the Viking orbiters continued close-up reconnaissance and exploration from 1976 to 1980. They and their landers compiled an impressive list of discoveries and achievements and generated new hypotheses of their own.

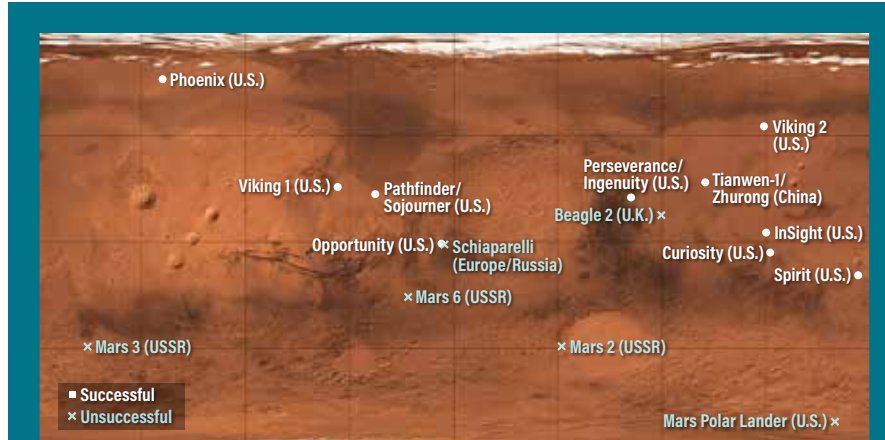
Then, after an unfortunate 17-year hiatus — a period that included the failure of the NASA flagship Mars Observer orbiter in 1993 — the space agency's more modest Mars Global

Mars is a busy place – it has become the most actively studied world in our solar system behind only Earth itself and the Moon.

Surveyor mission picked up the mantle of orbital reconnaissance in 1997.

Mars orbit has now been continuously occupied for nearly 25 years — initially by follow-on NASA missions, but more recently by orbiters from the space agencies of Europe, India, the United Arab Emirates, and China. Currently, an incredible eight robotic orbital emissaries from Earth ply the Red Planet's skies.

Many of these orbiters and their



DO OR DIE

Over the past five decades, Mars has hosted some spectacularly productive missions — but it has also been a graveyard for many spacecraft. Its thin atmosphere, just 1 percent as dense as Earth's, makes it difficult for landers, entering at speeds of up to 13,000 mph (21,000 km/h), to slow down. Mapped here is every spacecraft on the surface of Mars, whether the mission returned scientifically meaningful data or not. *ASTRONOMY: ROEN KELLY; IMAGE: NASA/USGS*



Mars' four towering shield volcanoes — and the immense plateau upon which they sit, named Tharsis — are visible in this Mariner 9 image taken Aug. 3, 1972. *NASA/JPL-CALTECH/TED STRYK*

science on the surface of the Red Planet, six of which are still active today: the InSight and Tianwen-1 landers, the Curiosity, Perseverance, and Zhurong rovers, and the Ingenuity helicopter drone. Mars is a busy place — it has become the most actively studied world in our solar system behind only Earth itself and our close companion, the Moon.

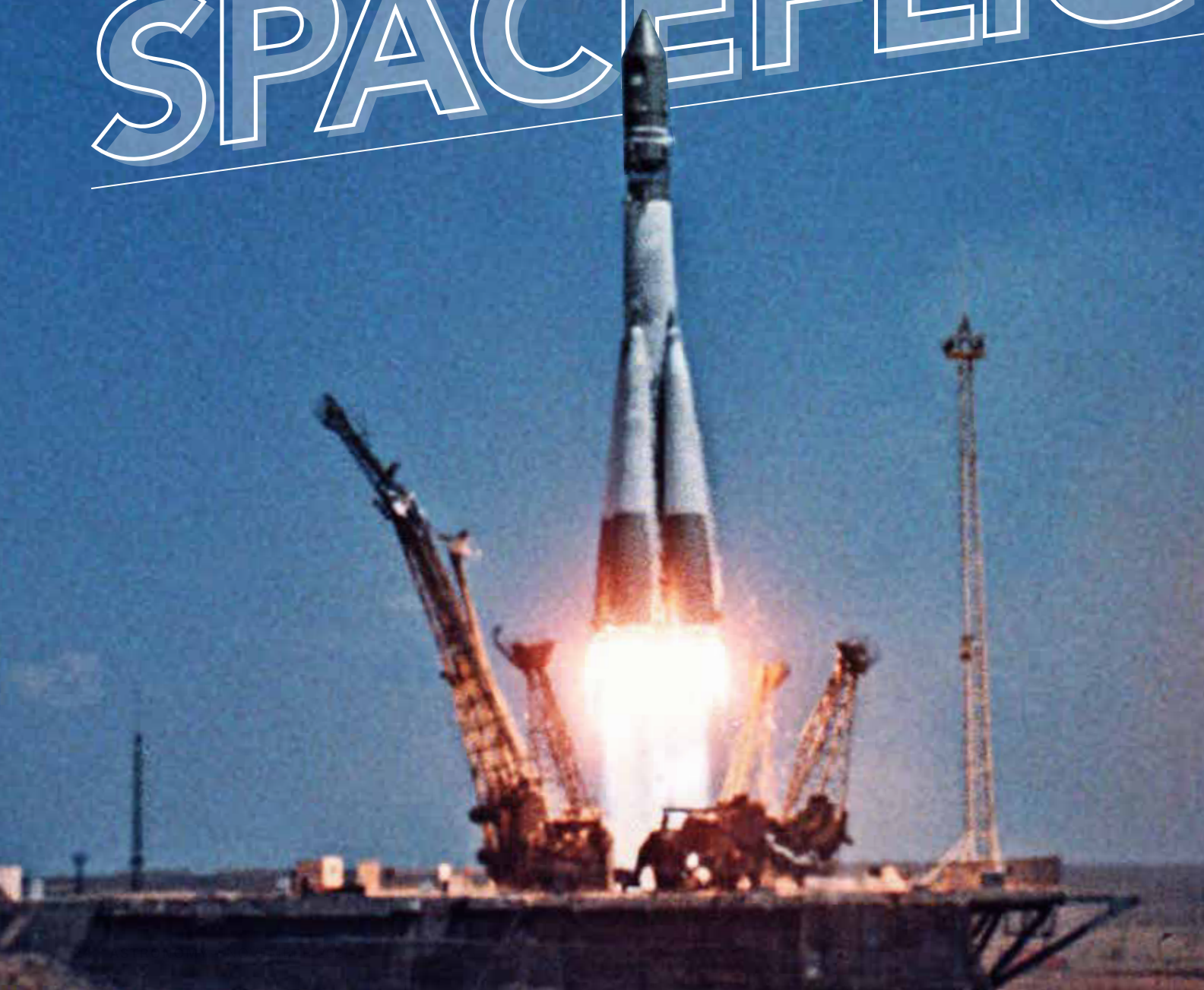
We don't know exactly where Mariner 9 is today. After exhausting the fuel for its attitude control thrusters, NASA turned off the spacecraft on Oct. 27, 1972. At the time, orbital dynamics engineers predicted that Mariner 9 would remain in orbit for perhaps another 50 years or more, after which time it would burn up in the martian atmosphere.

Perhaps sometime soon, then, one of our robotic avatars from the Blue Planet will witness a spectacular new shooting star blazing across the Red Planet's dusty sky — the final fireworks from Mariner 9, among the most productive and impactful deep-space missions ever flown. ☾

Jim Bell is an astronomer and planetary scientist at Arizona State University and has been involved in three NASA Mars orbiter missions and all five NASA Mars rover missions. **William Sheehan** was still in high school when he observed Mars' 1971 opposition with a 4.25-inch reflector. He is widely regarded as one of the world's leading historians of the Red Planet. Much of this article is based on their new book, *Discovering Mars: A History of Observation and Exploration of the Red Planet* (University of Arizona Press, 2021).

CELEBRATING 60 YEARS

of **HUMAN**
SPACEFLIG



The flights of Yuri Gagarin and Alan Shepard blazed a trail for human spaceflight that is still unfolding today.

BY BEN EVANS

BEFORE LEAVING EARTH for the International Space Station (ISS) last April, three smartly dressed spacemen — Oleg Novitsky, Pyotr Dubrov, and Mark Vande Hei — took time from their training to pause for a moment of reflection. In the half-gloom of a tiny office in Star City, Russia, they surveyed a faded world map, archaic telephones, and a clock perpetually halted at the instant of its owner's death. Later, as their greatcoats held back the chill of an early Moscow spring, they laid a splash of red blooms at a grave embedded in the brickwork of the city's Kremlin Necropolis.



Vostok 1 lifts off from Baikonur on April 12, 1961, cementing Yuri Gagarin's place in history as the first man in space. SPUTNIK/ALAMY STOCK PHOTO

Clockwise from upper left: Gagarin sits in the foreground during transport to the launchpad April 12, 1961. ESA

Alan Shepard sits in *Freedom 7* prior to his historic flight. Ultimately, he would spend more than four hours in the capsule while waiting to launch. NASA

STS-1 crew members John Young (left) and Robert Crippen pose with a model of the space shuttle for an official NASA portrait. NASA



From right to left: Gagarin sits with actor Vyacheslav Tikhonov, fellow cosmonaut Valentina Tereshkova, and actor Ivan Lyubeznov in this June 1963 photo.

RIA NOVOSTI ARCHIVE, IMAGE #16849/KHALIP/CC-BY-SA 3.0

These three spacefarers surely felt the presence of Yuri Gagarin as they paid tribute to that unassuming hero who, 60 years ago, kicked off a space odyssey that will likely never end.

MAKING A COSMONAUT

Gagarin's upbringing betrayed little of the icon he would become. Born March 9, 1934, into peasant stock in the Russian village of Klushino, his formative years were brutalized by World War II. He learned to read from old military manuals, pestered his father into helping him build miniature gliders, and found work as an apprentice foundryman. A love of aviation ultimately drew him to the Soviet air force, where he flew MiG-15 fighters out of Luostari airbase in Murmansk until he was hired for cosmonaut training in March 1960.

Gagarin excelled in training, exhibiting a sharp memory, quick reactions, and a



The spot near the town of Engels where Gagarin's feet found terra firma is today marked by a 40-foot-tall (12 m) inscribed obelisk. SOLOVEV/FOTO/DREAMSTIME

keen grasp of mathematics. But it was also the ordinariness of this fresh-faced 20-something that helped him win selection as the world's first space traveler, aboard Vostok 1. Gagarin represented the ideal communist pinup: a humble farm boy who rose up from rags to reach the stars. According to fellow cosmonaut Gherman Titov, the backup pilot for the flight, Gagarin was "a lad who made his dream come true, all by himself."

LET'S GO!

On April 12, 1961, Titov and Gagarin breakfasted on meat puree and toast with blackcurrant jam. They then donned their orange pressure suits and were bused to

the Baikonur launchpad on the wind-swept Central Asian steppe of what is now Kazakhstan. At the launch site, unable to share the Russian going-away tradition of three kisses on alternate cheeks, Gagarin and Titov instead clinked their helmets together in brotherly solidarity.

Inside the spherical cabin of his Vostok capsule, engineers tightened Gagarin's harness, armed his ejection seat, and fastened his oxygen hose. The spaceship was meant to function autonomously, for fear that separation anxiety from Earth might cause the cosmonaut to go mad once in space. At 9:07 A.M. Moscow Standard Time (MSK), the rocket — a converted R-7 Semyorka intercontinental ballistic missile — roared to life, climbing toward the heavens. "*Poyekhali!*" Gagarin cried, which translates to "Let's go!"

Gagarin later recalled "an ever-growing din," partly muffled by his helmet, as the R-7 climbed higher. The g-forces made speaking difficult. His heart rate soared from 66 to 158 beats per minute. By 9:18 A.M. MSK, he was safely in orbit. Before his eyes, a tiny Russian doll stowed on the spacecraft floated in midair — indicating the onset of weightlessness.

Reaching 203 miles (327 kilometers) in altitude, Gagarin smashed the previous world aviation altitude record of 32 miles (51 km), achieved March 30, 1961, by American Joe Walker in a NASA X-15 rocket-propelled aircraft. As Vostok 1 progressed east, tracking stations across Siberia serenaded him with musical greetings. At the Yelizovo station on the Kamchatka Peninsula, cosmonaut Alexei Leonov was treated to the first crude television image beamed from space. "I could not make out his facial features," Leonov remembered, "but I could tell from the way he moved that it was Yuri."

At 9:32 A.M. MSK, as Vostok 1 cut across the South Pacific, Radio Moscow broke the news: "The world's first

TIMELINE OF CREWED LAUNCHES

* Accurate as of July 20, 2021

1961

U.S. 2
Russia 2

1962

U.S. 3
Russia 2

1963

U.S. 3
Russia 2
U.S. X-15 plane reaches space

1964

U.S. 0
Russia 1

1965

U.S. 5
Russia 1

1966

U.S. 5
Russia 0

1967

U.S. 0
Russia 1
Apollo 1 fire; Soyuz 1 crashes on reentry

1968

U.S. 2
Russia 1

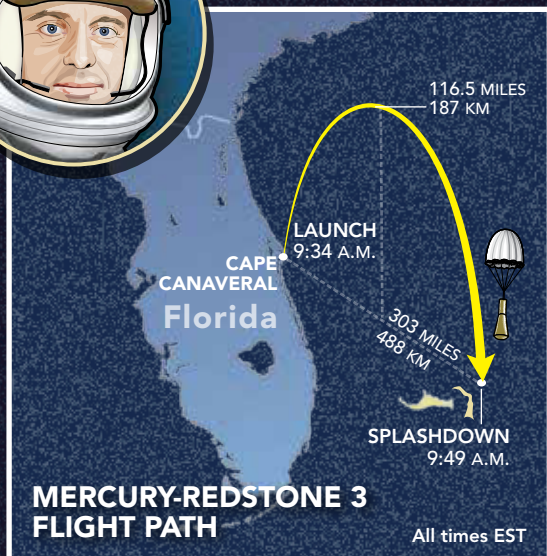
1969

U.S. 4
Russia 5
U.S. reaches Moon (Apollo 11)

ALAN SHEPARD

First journeys to space

YURI GAGARIN



Above: Shepard's flight lasted less than 16 minutes and covered a linear distance of 303 miles (488 km). *ASTRONOMY: ROEN KELLY*

Right: The flight of Vostok 1 launched from what is now the Baikonur Cosmodrome in Kazakhstan and lasted a little less than two hours, landing near Engels, Russia. During the flight, Gagarin passed through both sunset (over the Pacific Ocean) and sunrise (over the Atlantic). *ASTRONOMY: ROEN KELLY*

VOSTOK 1 FLIGHT PATH



spaceship, Vostok, with a man on board, was launched into orbit from the Soviet Union."

Less than two hours later, Vostok 1 plunged back to Earth. Gagarin ejected from the craft shortly after passing 22,000 feet (6,700 meters), safely parachuting to the ground.

AMERICA'S ANSWER

By early 1961, NASA had informed 37-year-old Alan Shepard that he would be the first man in space. He expected to fly in March, but when the chimpanzee Ham narrowly escaped with his life during an unhappy mission in January,

it raised eyebrows about the wisdom of such haste to beat the Soviets. An additional uncrewed flight in March assuaged those worries, but at the cost of pushing Shepard's flight back to May.

Then came Vostok 1. Although U.S. listening posts were already aware of Gagarin's mission, the tensions of the Cold War meant the announcement that aired April 12 on Radio Moscow still jarred when they heard it. Gagarin's successful flight meant the U.S. fell another lap behind in the race to conquer space. "We had 'em by the short hairs," Shepard would repeat to anyone who would listen, following the news, "and we gave it away."

Shepard was a gruff New Englander and progeny of a wealthy and dedicated military family. His boundless energy had propelled him two grades ahead at school, while an adventurous spirit, keen wit, and a single-minded determination to be the best led the U.S. Navy to handpick Shepard to test its most advanced aircraft.

Chosen as one of NASA's original Mercury Seven astronauts in 1959, Shepard's thirst for pushing boundaries would ultimately take him to the Moon. Still, his selection as America's first space traveler was undoubtedly his proudest accomplishment. "Not because of the fame or the recognition," Shepard said,

1970

U.S. 1
Russia 1
Apollo 13 oxygen tank explodes

1971

U.S. 2
Russia 2
Salyut 1 launched; Soyuz 11 crew dies

1972

U.S. 2
Russia 0

1973

U.S. 3
Russia 2
Skylab launched

1974

U.S. 0
Russia 3

1975

U.S. 1
Russia 4

1976

U.S. 0
Russia 3

1977

U.S. 0
Russia 3

1978

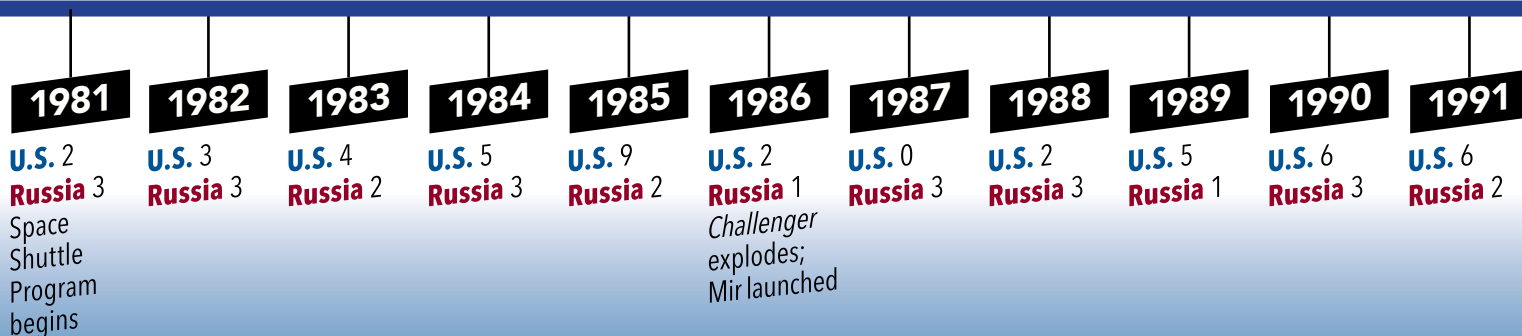
U.S. 0
Russia 5

1979

U.S. 0
Russia 2

1980

U.S. 0
Russia 6





Above: President John F. Kennedy and First Lady Jacqueline Kennedy watch the launch of *Freedom 7* on television. WORLD HISTORY ARCHIVE/ALAMY STOCK PHOTO



Left: Shepard with his capsule aboard the USS *Lake Champlain* after splashing down a few hundred miles southeast of Cape Canaveral, Florida. NASA

enormous rockets to carry human crews to the Moon. When America eventually won the lunar race in July 1969, the Soviets took a new direction: building and occupying the world's first space stations.

Each victory was hard-won. In 1967, three Americans died in a spacecraft fire on the launchpad, while a Russian was killed when his capsule's parachute lines became entangled during descent. Three more astronauts narrowly escaped death when an explosion crippled the Moon-bound Apollo 13 spacecraft. In June 1971

— after setting a new world record for the longest space mission — a trio of cosmonauts suffocated when their Soyuz 11 capsule depressurized during reentry.

Against this tortured backdrop was the inescapable truth that exploring space with people was monstrously expensive and difficult. No sooner had Neil Armstrong planted his boots on the Moon's Sea of Tranquility than America began looking for a cheaper and more efficient way to send humans to space.

Ultimately, out of a toxic mix of political and military compromise, the space shuttle was born. This new vehicle promised to revolutionize and routinize spaceflight. After rocketing to orbit, it would glide back to Earth, landing on a runway like an airplane.

BIGGER DREAMS — AND RISKS

The maiden voyage of space shuttle *Columbia* was to be helmed by John Young — America's premier astronaut and one of only 12 people to walk on the Moon — and co-pilot Robert Crippen. Although eager, Young harbored no illusions about the possibility that he might never return from this first mission of the Space Shuttle Program.

The shuttle was danger on steroids: a delta-winged craft awkwardly bolted astride a fuel-filled external tank and flanked by two solid rocket boosters (SRBs). With no meaningful crew escape mechanism, the shuttle's ascent profile included several phases, ominously called black zones, in which major emergencies were guaranteed to be fatal.

Ejection seats, parachutes, and pressure suits were available on the first four test flights — STS-1 through STS-4. But these would be phased out for so-called operational missions, starting with STS-5. And ejecting directly into toxic rocket exhaust left Young more than a little skeptical of the escape plans. Even if the astronauts did successfully eject, their parachutes might not open in time to save them.

One afternoon, fellow astronaut Joe Allen bought Young lunch in the cafeteria. When Young promptly attempted to pay him back, Allen laughed and told Young to forget it. "No," Young retorted. "You don't go fly these things when you got debts. All my debts are paid."

THE FIRST SHUTTLE FLIGHT

Columbia's first launch attempt on April 10, 1981, was stalled when a timing glitch popped up in one of the shuttle's computers. The launch was rescheduled for April 12 — coincidentally the 20th anniversary of Gagarin's Vostok 1 flight.

One minute before launch, *Columbia*'s three main engines — which blew up with



concerning regularity during ground tests — were ready to go as the shuttle's internal computer took control of the launch sequence.

At T-minus 16 seconds, water flooded the launchpad to reduce the energy reflected up at the shuttle during liftoff. At T-minus 10 seconds, a flurry of sparklers came alive beneath the main engines to burn off residual hydrogen. At T-minus 6.6 seconds, those engines roared to life.

With the engines at full tilt, the countdown hit zero. The SRBs ignited with a dazzling flame and a harsh staccato crackle that shook the 3,500 spectators gathered along the beaches and roadways of Cape Canaveral. Explosive bolts anchoring the behemoth to the pad released at 7 A.M. EDT, allowing 7 million pounds (3.1 million kg) of thrust to loft the shuttle into the sky.

In the cockpit, Young and Crippen felt the vehicle rock back and forth. The incessant vibrations rendered their instruments blurry but still readable. Those vibrations diminished once the boosters fell away and *Columbia*, powered only by its engines, sailed smoothly into orbit.

Throughout it all, Young's heart rate climbed no higher than 90 beats per minute, while Crippen's peaked at almost 130. Young later joked that his old heart simply refused to beat any quicker. Flight Director Neil Hutchinson offered another explanation: The cool, unflappable Young must have been asleep the whole time.

Two days later, *Columbia* performed a searing hypersonic descent, targeting the runway at Edwards Air Force Base in California. During reentry, temperatures



Columbia lifts off on April 12, 1981, on the maiden voyage of the Space Shuttle Program. The shuttle's large external tank was painted white for aesthetic purposes; NASA ultimately ceased this practice, which is why the tank appears orange on later shuttle missions. NASA

descent and phenomenal speed caused hearts to pound. Barreling through the sky at an angle some seven times steeper than that of an airliner — and at almost twice the speed — Young pulled back on the stick, morphing the craft from a falling brick into a flying machine of exquisite grace.

At 10:20 A.M. PDT, *Columbia* touched down at 212 mph (341 km/h), its wheels kicking up a rooster tail of hard-packed sand. As the

shuttle came to a halt following a 1.9-mile (3 km) rollout, Young's characteristic drawl came over the radio: "Do I have to take it to the hangar, Joe?" he asked mission control's Joe Allen, serving as Entry Capsule Communicator, or CapCom.

Allen chuckled before answering, "We're gonna dust it off first."



Two days after launch, *Columbia*'s wheels touch down at Edwards Air Force Base in California as the shuttle makes its first successful landing. NASA

doubled, then tripled, then quadrupled, as ionized gases around the shuttle morphed from salmon pink to reddish orange. The astronauts could only marvel at the hell-fire raging inches from their noses. As expected, this plasma sheath around the fast-moving shuttle temporarily severed radio communications. Additionally, a lack of tracking stations meant the shuttle was out of contact for 20 uncomfortable minutes. Once contact was reestablished, Crippen jubilantly remarked, "What a way to come to California."

For spectators on the ground, more attuned to the serene approaches of commercial jets, the shuttle's precipitous

STUTTERING STEPS

Despite its triumphs, STS-1 was not a perfect success. For example, struts that held *Columbia* to its fuel tank buckled at liftoff, forcing NASA to strengthen them for future flights. Additionally, several of the shuttle's thermal tiles suffered damage during ascent and required replacement once back on the ground. (A similar problem doomed *Columbia* in 2003 when, during launch, a piece of foam fell from the external tank and struck the left wing, damaging the thermal protection system to the point of failure during reentry.)

But in April 1981, few foresaw that both *Columbia* and *Challenger* would vanish in dreadful tragedies, taking 14 lives. Instead, NASA hoped its planned fleet of at least four reusable shuttles

2003

U.S. 1
Russia 2
China 1
Columbia disintegrates on reentry; China reaches space

2004

U.S. 3
Russia 2
First commercial spaceflight (*SpaceShipOne*)

2005

U.S. 1
Russia 2
China 1

2006

U.S. 3
Russia 2

2007

U.S. 3
Russia 2

2008

U.S. 4
Russia 2
China 1

2009

U.S. 5
Russia 4

2010

U.S. 3
Russia 4

2011

U.S. 3
Russia 4
Space Shuttle Program ends; Tiangong-1 launched

— *Atlantis*, *Challenger*, *Discovery*, and *Columbia* — would launch weekly with crews of up to seven, allowing more rapid access to space than ever before.

Few also imagined that shuttles would go on to visit Russia's Mir space station or the ISS after it. And no one dreamed that returning humans to the Moon would use the giant Space Launch System, whose core stage, engines, and boosters draw their design heritage directly from the shuttle.

The last shuttle mission, STS-135, landed July 21, 2011. And though the Space Shuttle Program never quite fulfilled its promise of rapid and routine access to space, it remains an iconic symbol of American high technology.

A NEW ERA

Gagarin's Vostok 1 flight served as a truly transformative moment. Over the next six decades, 504 men and 65 women representing 41 sovereign nations and a half-dozen religious faiths have ventured to space. Twenty-four Apollo astronauts have voyaged to the Moon, with 12 leaving footprints on its dusty surface. And 42 men and women have spent more than a year of their lives in space.

Gagarin himself saw little of this unfolding adventure. Officials barred the highly prized Soviet poster boy from a second spaceflight after the Soyuz 1 crash in 1967 claimed the life of his close friend Vladimir Komarov. Gagarin eventually battled his way back to active status and might have even flown to space again — but before that chance presented itself, he died in an airplane crash in March 1968. He was 34 years old.

Now, the world is launching into a new space race. NASA's Artemis Program aims to put boots on the Moon by 2024. China and Russia have plans to collaborate on a lunar base later this decade. And later this year, the four crew members of



SpaceX's Starship SN9 (top) sits on the launchpad in Boca Chica, Texas, prior to its early 2021 high-altitude flight test. Blue Origin's New Shepard Crew Capsule (above) parachutes back to Earth during an uncrewed April 2021 flight to space. SPACEX, BLUE ORIGIN

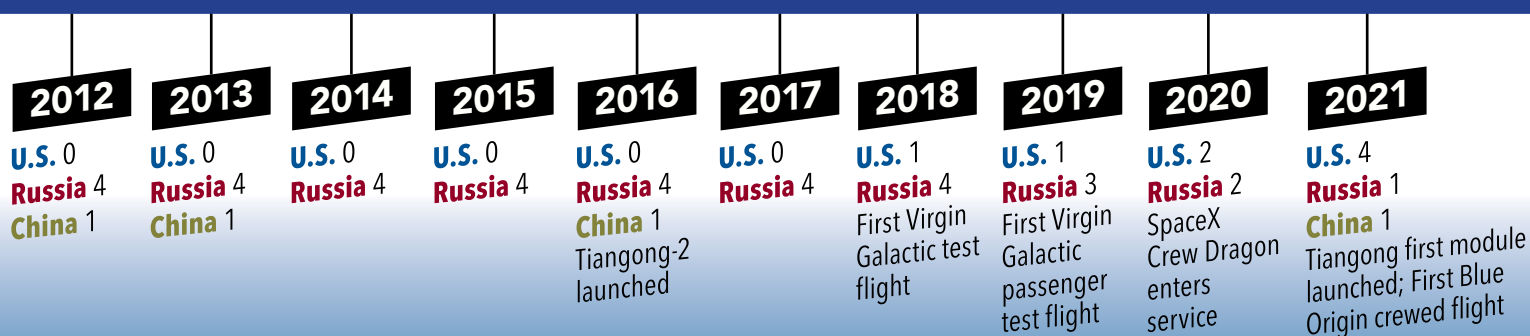
the Inspiration4 mission hope to carry out the first all-civilian spaceflight inside a SpaceX Crew Dragon capsule.

Also chomping at the bit to dominate the suborbital market is Blue Origin, whose reusable New Shepard rocket and six-seat crew module sent four civilian astronauts to the edge of space July 20. Similarly, Virgin Galactic's successful July 11 SpaceShipTwo flight brings it ever nearer to making suborbital tourism a reality, aiming to commence commercial operations in the latter half of 2022. And Houston-based Axiom is planning private missions and add-on modules to the ISS beginning in the next few years.

At Boca Chica in Texas, meanwhile, SpaceX continues to test its giant Starship, recently selected by NASA to return humans to the lunar surface for the first time since 1972. And the dearMoon project hopes to see the first lunar tourists fly around Luna — à la Apollo 8 — aboard a SpaceX Starship in just two years' time.

The future of spaceflight seems brighter than ever, if we're willing to embrace it. As Gagarin, the man who started it all, said: *Poyekhali!* Let's go! 🚀

Ben Evans has been fascinated by space since childhood. He has written extensively on the history of human spaceflight.



SKY THIS MONTH

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING



NOVEMBER 2021 A dazzling evening lineup

» Venus, Jupiter, and Saturn dominate the evening sky with lots of planetary action in November. Highlights include Venus' quickly changing phase; Jupiter's atmosphere, Great Red Spot, and Galilean moon transits; and Saturn's stunning rings. Uranus reaches opposition and is on view all night, and for a bigger challenge, hunt down distant Neptune.

Venus crosses into Sagittarius Nov. 1 and is visible within half an hour of sunset, low and bright in the southern sky. At magnitude -4.5 , it is

unmistakable. Venus crosses the broad swath of the Milky Way during the first two weeks of the month. The planet stands less than 3° south of the Lagoon Nebula (M8) on Nov. 6, offering astrophotographers a fine target. Take your time framing Venus and the Milky Way, along with foreground features silhouetted against the sky.

On Nov. 7, a slender crescent Moon stands roughly 3° west of Venus. Earthshine makes the unlit portion of the Moon visible against the Milky Way for those with a good view of the

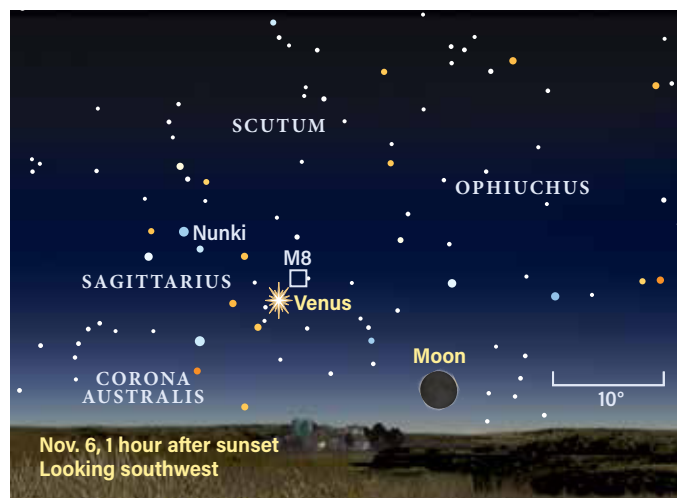
western horizon and clear, transparent air. View Venus through binoculars on Nov. 14 and look for the misty smudge 3° north — this is magnitude 5 globular cluster M22. Also check out Venus on Nov. 19, when it sits a half-Moon's width

from the 2nd-magnitude star Nunki (Sigma [σ] Sagittarii). Through a telescope, Venus reveals a 48-percent-lit disk spanning $26''$ on Nov. 1. Watch it change throughout November, slimming to a fine 29-percent-lit crescent by Nov. 30 and increasing to $39''$ wide.

By the end of November, Venus, Saturn and Jupiter span a 35° -long stretch of the ecliptic across the southwestern sky. Saturn and Jupiter both lie in Capricornus the Sea Goat all month. Between Nov. 7 and 11, a waxing crescent Moon follows this line of planets.

We'll visit Saturn next, which lies in the constellation's western half and moves slowly eastward as the month progresses. Saturn is visible as twilight descends and sits farther along the ecliptic than Venus; consequently, it remains visible longer, setting soon after 11:30 P.M. local time on Nov. 1 and by 9 P.M. on

Venus visits the Lagoon



Astrophotographers won't want to miss this shot: On Nov. 6, Venus sits less than 3° south of the Lagoon Nebula (M8). ALL ILLUSTRATIONS: ASTRONOMY: ROEN KELLY

OBSERVING HIGHLIGHT

MERCURY is occulted by the Moon Nov. 3 during daylight hours as seen from the eastern portion of the U.S. and Canada.



Nov. 30. It starts November at magnitude 0.5 and dims by 0.1 magnitude by month's end. A waxing crescent Moon lies in its vicinity Nov. 9 and 10.

The best telescopic views of Saturn occur within a few hours of sunset. By 10 P.M. local time Nov. 1, Saturn is less than 20° high, so our atmosphere distorts the view. Saturn's disk spans 17" and the rings' major axis stretches 38" wide. The increasing distance between Earth and Saturn this month reduces its size by a barely noticeable 5 percent during November. Saturn lies 10.4 astronomical units or 967 million miles from Earth by the end of the month.

The fine ring system is tilted by 19° to our line of sight, showing off their northern face while the southern hemisphere of the planet peeks out below the outer Ring A.

Titan, Saturn's brightest moon, shines at magnitude 8.7 and is easily spotted through any telescope. You'll find it north of the planet Nov. 6 and 22, and south of the planet Nov. 14 and 30.

Three fainter (magnitude 10) moons orbit closer in. Tethys, Dione, and Rhea swap positions quickly, sometimes noticeable in an hour or so. Enceladus is challenging to spot at magnitude 11.7, close to the bright rings.

Iapetus reaches inferior conjunction Nov. 18, when it

— Continued on page 38

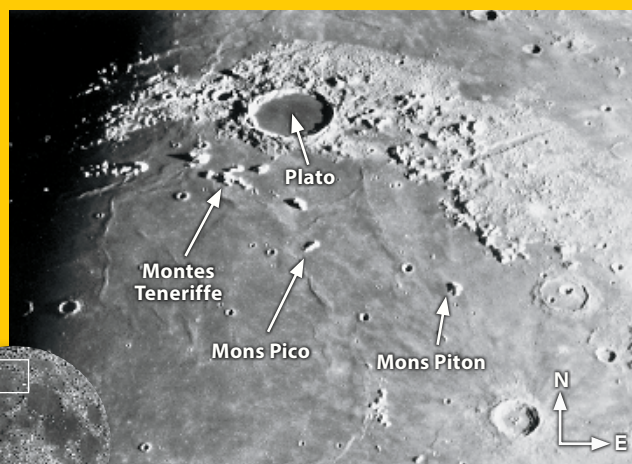
RIISING MOON | Standout mounts

A NIGHT after the Moon bulges past a perfect half, the Sun rises over the great lava fields of Mare Imbrium, brightly illuminating a series of mountain peaks jutting suddenly upward. In their own way, they are just as dramatic as the large oval Plato Crater to their north.

Mons Pico stands about a mile and a half high above its footprint of 15 miles by 10 miles. During the evening of the 13th, it is easy to notice Pico's shadow retreating.

Faster yet are the long dark triangles cast by Montes Teneriffe to the west — have a peek every 20 minutes or so. Once thought to be volcanic, the new perspective brought on by the first robotic lunar missions finally let astronomers piece together the origin of these hills. But it was a completely different area to their

Montes Teneriffe, Mons Pico, Mons Piton



Many of the mountain ranges and peaks you'll find in Mare Imbrium aren't volcanic in origin. CONSOLIDATED LUNAR ATLAS/UA/LPL.

INSET: NASA/GSFC/ASU

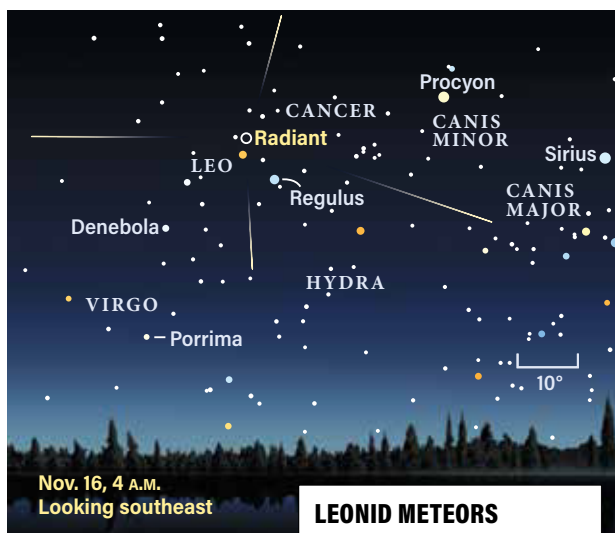
west — Mare Orientale — that provided the answer we couldn't see from Earth.

Multiple clean, concentric rings of mountains surrounding Orientale let scientists infer a similar impact origin for Pico. Long after the blast, multiple

lava episodes filled the lowlands and buried the lower tops, leaving only the tallest peaks of the curving chains poking out. Piton is another high point to the southeast, while La Hire stands on the opposite side of Mare Imbrium.

METEOR WATCH | Dodging the Full Moon

Leonid meteors



Nov. 16, 4 A.M.
Looking southeast

A Full Moon near the Leonids' peak means you're better off searching for shower meteors the week before maximum.

LEONID METEORS

Active dates: Nov. 6–30

Peak: Nov. 17

Moon at peak: Waxing gibbous

Maximum rate at peak:
10 meteors/hour

THE ANNUAL LEONID meteor shower peaks Nov. 17 and is active between Nov. 6 and 30. This month's Full Moon shortly after maximum strongly affects the shower's visibility, so conditions are unfavorable around the peak. Focusing on the week prior to maximum is your best bet. On Nov. 12, the Moon sets at local midnight, just as Leo rises in the east. By Nov. 16, the Moon sets around 4 A.M. local time, offering more than an hour of dark skies before twilight interferes. This is likely your best morning to observe the Leonids.

The zenithal hourly rate of 10 meteors per hour this year means that even by the 16th, very few shower members will be observed, barring any surprises. The Leonid shower is associated with Comet 55P/Swift-Tuttle, which last reached perihelion in 1998.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. November 1
8 P.M. November 15
7 P.M. November 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- ⊕ Globular cluster
- Diffuse nebula
- ⊕ Planetary nebula
- Galaxy

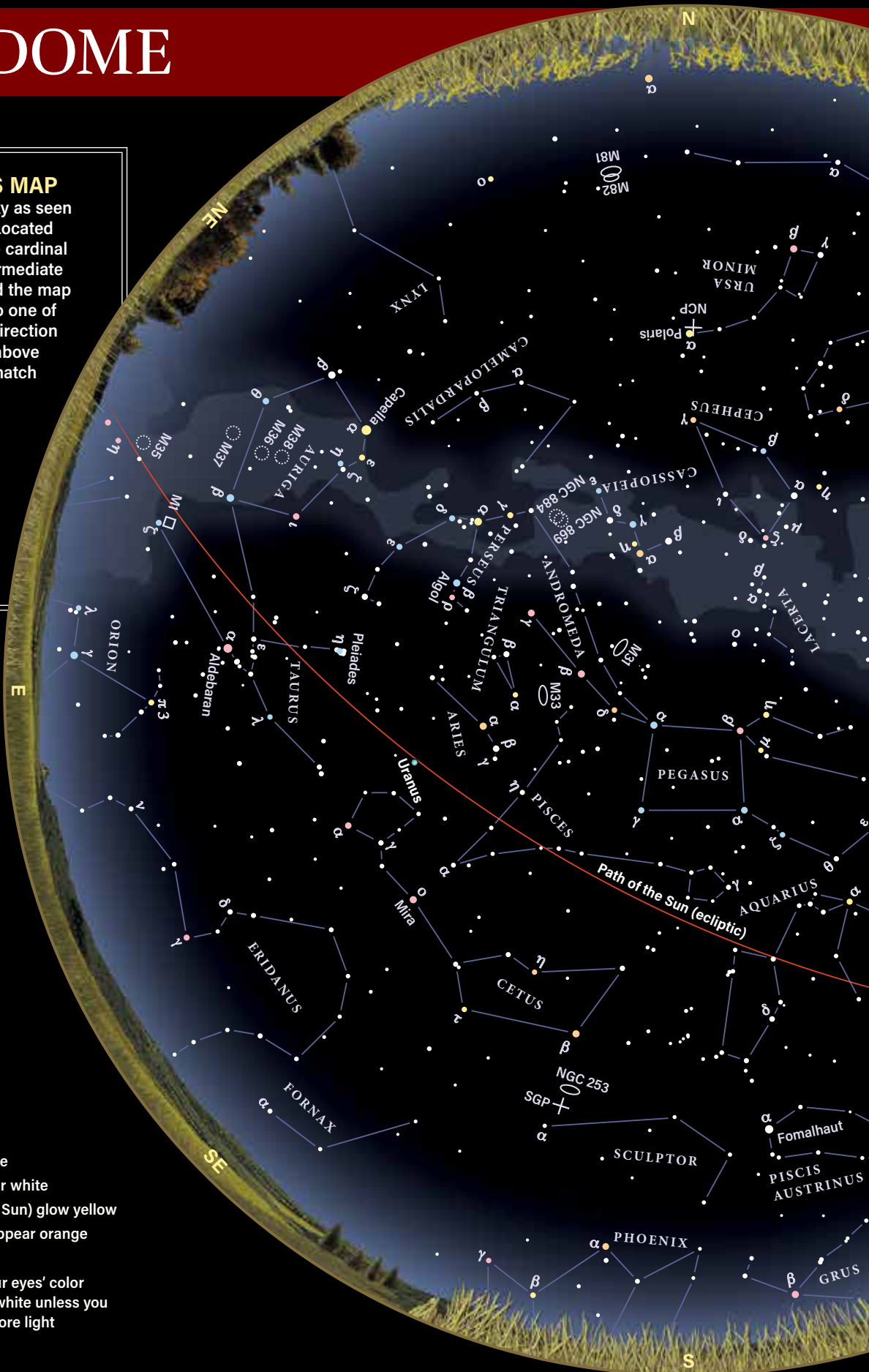
STAR MAGNITUDES

- Sirius
- 0.0 ● 3.0
- 1.0 ● 4.0
- 2.0 ● 5.0

STAR COLORS































A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light









NOVEMBER 2021

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	 1	 2	 3	 4	 5	 6
 7	 8	 9	 10	 11	 12	 13
 14	 15	 16	 17	 18	 19	 20
 21	 22	 23	 24	 25	 26	 27
 28	 29	 30				

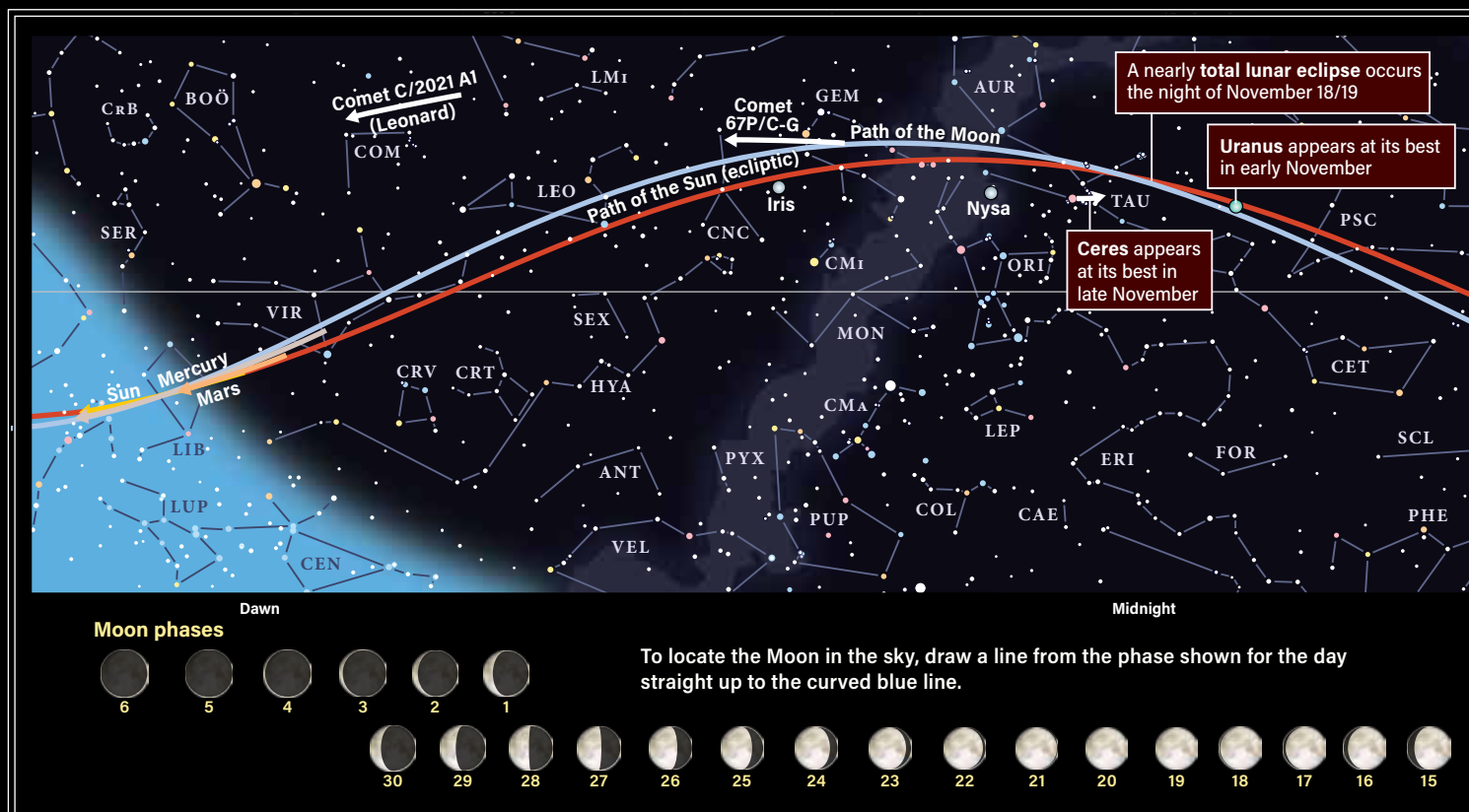
ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

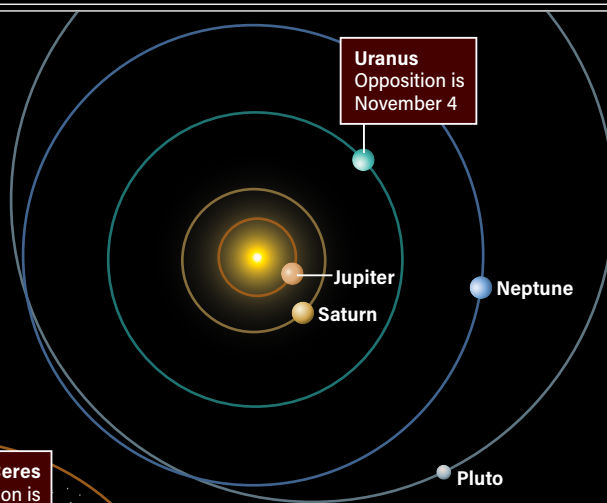
- 3 The Moon passes 1.2° north of Mercury, 3 P.M. EDT
- 4  New Moon occurs at 5:15 P.M. EDT
Uranus is at opposition, 8 P.M. EDT
- 5 The Moon is at perigee (222,975 miles from Earth), 6:18 P.M. EDT
- 7 The Moon passes 1.1° north of Venus, midnight EST
- 10 The Moon passes 4° south of Saturn, 9 A.M. EST
- 11  First Quarter Moon occurs at 7:46 A.M. EST
The Moon passes 4° south of Jupiter, noon EST
- 13 The Moon passes 4° south of Neptune, 2 P.M. EST
- 17 Leonid meteor shower peaks
The Moon passes 1.5° south of Uranus, 9 P.M. EST
- 19  Full Moon occurs at 3:57 A.M. EST; partial lunar eclipse
- 20 The Moon is at apogee (252,450 miles from Earth), 9:13 P.M. EST
- 26 Dwarf planet Ceres is at opposition, 11 P.M. EST
- 27  Last Quarter Moon occurs at 7:28 A.M. EST
- 28 Asteroid Vesta is in conjunction with the Sun, 5 A.M. EST
Mercury is in superior conjunction, midnight EST

PATHS OF THE PLANETS



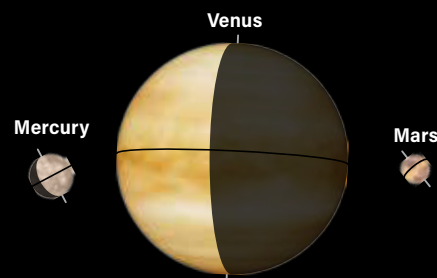
THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



THE PLANETS IN THE SKY

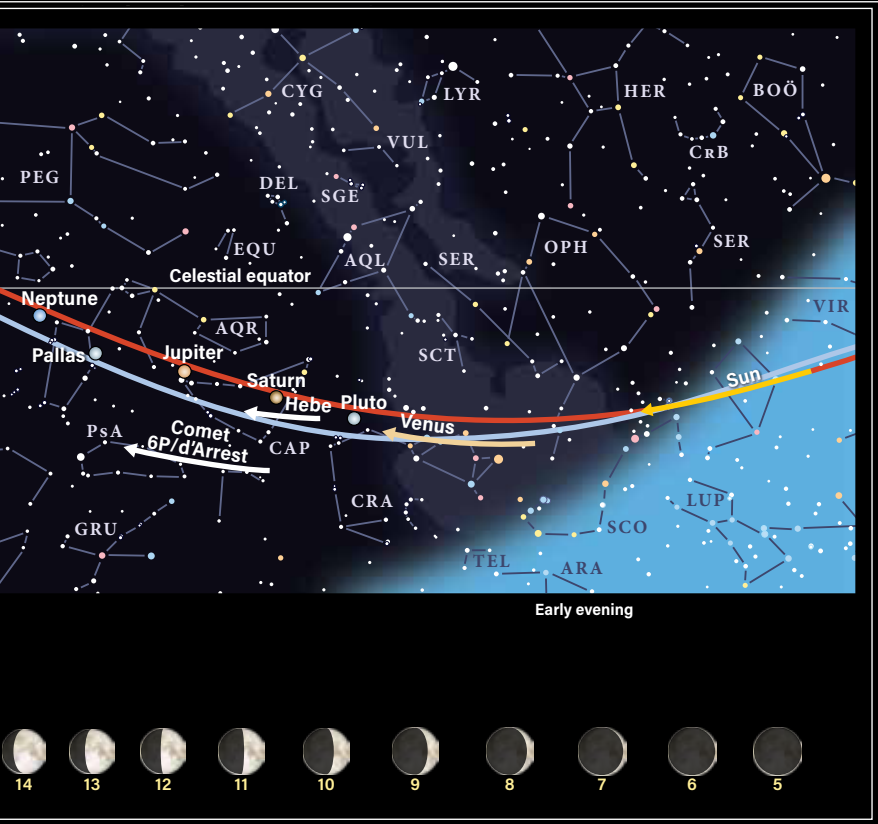
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.



PLANETS	MERCURY	VENUS
Date	Nov. 1	Nov. 15
Magnitude	-0.9	-4.7
Angular size	5.8"	30.6"
Illumination	79%	40%
Distance (AU) from Earth	1.153	0.545
Distance (AU) from Sun	0.346	0.725
Right ascension (2000.0)	13h24.8m	18h37.5m
Declination (2000.0)	-6°41'	-26°56'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

NOVEMBER 2021



Callisto



Europa



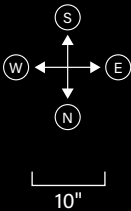
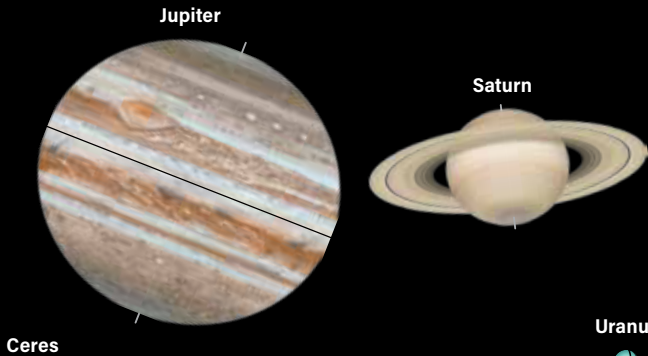
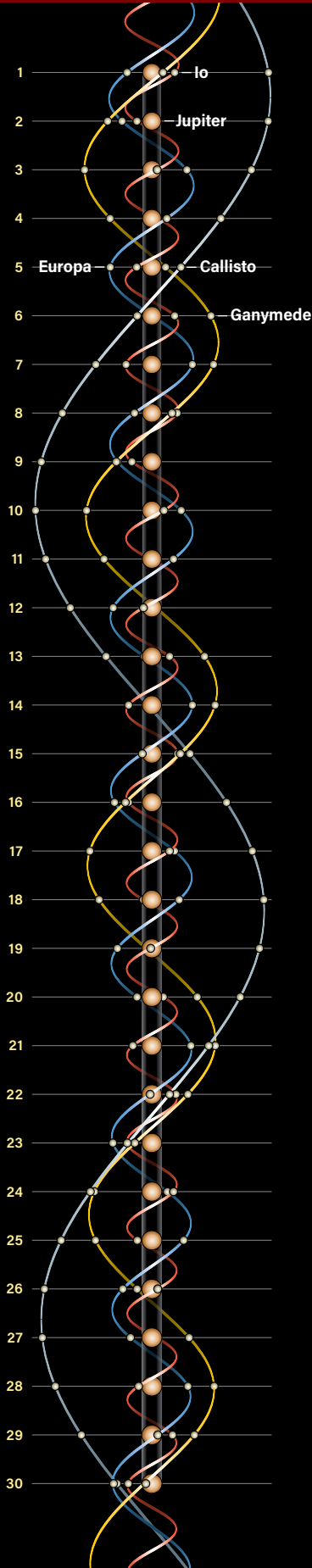
Io



Ganymede

JUPITER'S MOONS

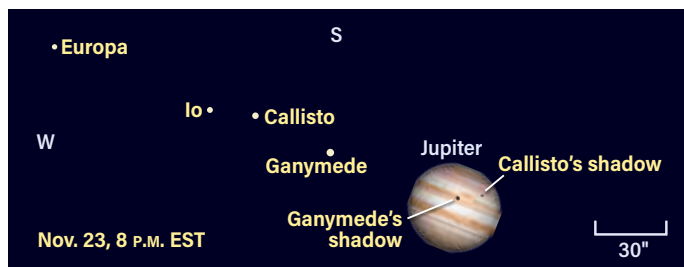
Dots display positions of Galilean satellites at 10 P.M. EST on the date shown. South is at the top to match the view through a telescope.



MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Nov. 30	Nov. 15	Nov. 15	Nov. 15	Nov. 15	Nov. 15	Nov. 15
1.6	7.3	-2.4	0.6	5.7	7.7	15.2
3.8"	0.7"	40.3"	16.4"	3.8"	2.3"	0.1"
99%	100%	99%	100%	100%	100%	100%
2.490	1.792	4.891	10.139	18.756	29.450	34.858
1.576	2.756	5.003	9.930	19.729	29.921	34.403
15h12.0m	4h26.6m	21h44.0m	20h40.9m	2h39.0m	23h25.7m	19h46.5m
-17°39'	16°32'	-14°46'	-19°10'	15°03'	-4°57'	-22°54'

SKY THIS MONTH — Continued from page 33

Traveling companions 🔭



In late November, Jupiter experiences a double shadow transit as dark blots from Ganymede and Callisto cross the planet's face together.

appears closer to Saturn than usual. It lies within 1' of the planet from Nov. 17 to 19. Iapetus moves west of Saturn in the latter half of the month, turning its brighter face earthward. See if you can spot this moon shining at about 11th magnitude midmonth, and slightly brighter toward the end of November.

Brilliant **Jupiter** shines at magnitude -2.5 in eastern Capricornus and remains about 16° east of Saturn all month. It moves slowly west; its motion relative to 3rd-magnitude Deneb Algedi will be obvious every few nights. It lies 1.9° northwest of the star on Nov. 1, passes due 1.6° north Nov. 22, and moves to a point 2.2° northeast of the star by Nov. 30.

The best views of Jupiter occur in late twilight, when it stands one-third of the way from the horizon to the zenith in the southwest. The fine cloud features, the twin dark equatorial belts, and the Great Red Spot are visible through small telescopes. The planet's brisk rotation (just under 10 hours) shows features changing position within a single evening. Jupiter sets soon after midnight on Nov. 1 and by 11 P.M. local time on Nov. 30.

Its four Galilean moons wander with periods of 1.8 to 17 days. Each moon also undergoes occultation by Jupiter, is hidden by Jupiter's shadow in

an eclipse, and transits with its associated shadow across the disk. The narrow observing window reduces the number of observable mutual satellite events, but two this month are worthy of attention. Note that more events occur than are listed here.

On Nov. 19, find Io just off Jupiter's eastern limb and

Ganymede near the western limb. Io begins to transit the disk at 8:33 P.M. EST and is joined by its shadow at 9:53 P.M. EST. Ganymede approaches the western limb of the planet and disappears in an occultation at 10:35 P.M. EST, while Io and its shadow are still on the disk.

Nov. 23 sees a rare double shadow transit. Ganymede and Callisto project the largest shadows on the jovian cloud tops; to see both at once is special. East Coast observers will see Ganymede's shadow appearing at 6:08 P.M. EST, followed soon after by Callisto's shadow at 6:52 P.M. EST. The shadows remain on the disk throughout the early evening for most of the country, until Ganymede's shadow exits by 9:39 P.M. EST, followed by Callisto's shadow at

WHEN TO VIEW THE PLANETS

EVENING SKY

Venus (southwest)
Jupiter (south)
Saturn (south)
Uranus (east)
Neptune (southeast)

MIDNIGHT

Jupiter (southwest)
Uranus (southwest)
Neptune (west)

MORNING SKY

Mercury (east)
Mars (east)
Uranus (west)

11:03 P.M. EST — after Jupiter sets in that time zone but visible across the rest of the country.

Neptune is located in Aquarius the Water-bearer, shining at magnitude 7.7. It remains visible until after

COMET SEARCH | In preparation

NEXT MONTH'S Comet C/2021 A1 (Leonard) is set to thrill. To get the most out of it, first hone your skills on 67P/Churyumov-Gerasimenko.

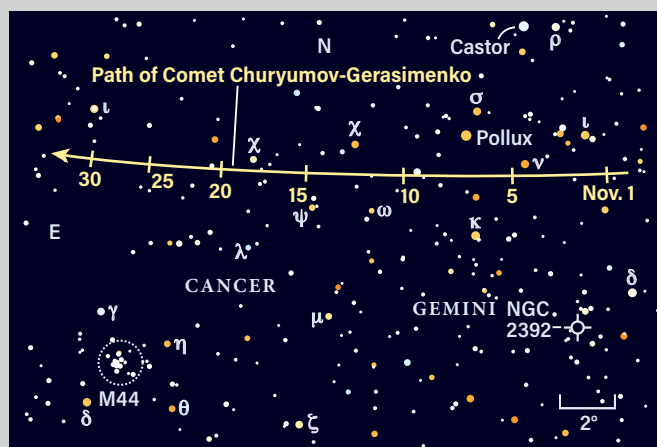
Experienced observers see more detail than beginners because they've trained their brains to pick up subtle features. Similarly for imagers, whether you're new or just rusty, you'll make more mistakes without practice.

Looping in from Jupiter's realm, Churyumov-Gerasimenko should glow between 8th and 9th magnitude. By midnight, it is more than 20° high in the east. Use the Crab Nebula (M1) as a brightness benchmark. Under country skies, a 4-inch scope will easily catch the Crab and the comet at low power. Both are a tough go from the city.

Training starts now: Bump up the magnification to 120x or so. Don't worry that higher power makes the comet seem dimmer. Seeing large, faint objects is a specialty of our dark-adapted eyes; tap the scope gently to trigger their motion-detector circuits. The comet's eastern flank (closest to the horizon and the Sun) will be well defined by the solar wind.

After the 10th, switch from evening to predawn observing to get seven more moonless sessions. Churyumov-Gerasimenko is then positioned very high in the sky. As November closes, brightening Leonard shares the same binocular field as globular star cluster M3 — can you tell which is which?

Comet 67P/Churyumov-Gerasimenko 🔭

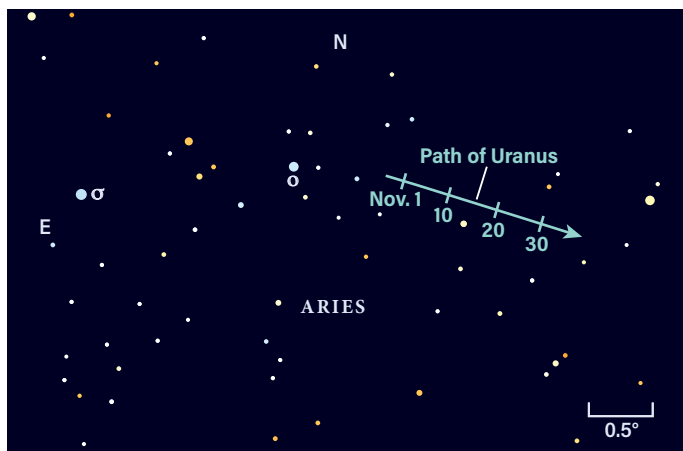


Comet Churyumov-Gerasimenko skims south of the Twins' heads in early November. It then passes into Cancer, flying nearly 7.5° north of M44.

LOCATING ASTEROIDS |

Hiking the Hyades

Slow travels  



Uranus reaches opposition Nov. 4. It is visible all night, traveling through the sparse skies of southern Aries.

midnight all month. Binoculars will show it standing just over 3° northeast of the 4th-magnitude star Phi (φ) Aquarii on Nov. 1. The gap between the star and planet shrinks by only 15' during the month as Neptune approaches its stationary point, which occurs Dec. 1.

To find Phi Aquarii, note that it stands roughly 8° south of the Circlet in Pisces. You can also use a pair of 6th-magnitude stars east of Phi in same binocular field of view — Neptune forms an isosceles triangle with this pair.

By the end of the month, Neptune lies 2.8 billion miles from Earth and its disk spans 2" through a telescope. Use high magnification on a steady night of seeing to observe its bluish-green disk. Neptune stands 5° northwest of a gibbous Moon Nov. 13.

Uranus reaches opposition Nov. 4 and remains visible all night. The ice giant lies about 18° southwest of the Pleiades in a sparse region of southern Aries. Shining at magnitude 5.7, Uranus starts the month 0.8° due west of Omicron (ο) Arietis,

a star also at magnitude 5.7 and itself 5° due north of the 4th-magnitude star Mu (μ) Ceti. By Nov. 17, when Uranus stands 1.8° northwest of a near-Full Moon, the planet is 1.5° west of Omicron Arietis, which is 1.7° due north of the Moon. Uranus continues westward, ending the month 2° west of Omicron.

The best time to view Uranus through a telescope is when it's highest in the sky around local midnight. The planet spans 4" — tiny to be sure, but resolvable through many telescopes as a disk. Its distinctive greenish-blue hue is marvelous to observe from 1.75 billion miles away.



Mercury continues to hang low in the southeastern sky before sunrise. On Nov. 1, Spica stands 4.2° due south of Mercury but is two magnitudes fainter. Binoculars may show the star if twilight doesn't drown it out. Mercury shines at magnitude -0.8 and brightens slowly but concurrently dips closer to the Sun.

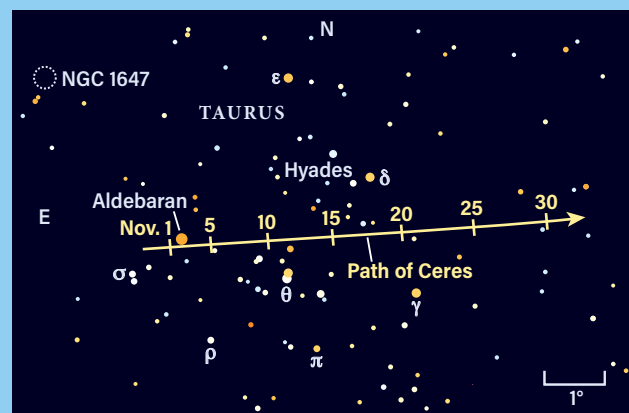
A crescent Moon occults Mercury on Nov. 3 during daylight as seen from the eastern

A CLUSTER-CROSSING BRIGHT ASTEROID, what luck! Dwarf planet 1 Ceres saunters across the face of Taurus — super simple to locate after midevening, when the Bull's ruddy eye, Aldebaran, is 15° high in the eastern sky. Until the 4th, Ceres is brighter than any other star within 20' of this luminary.

Glowing at magnitude 7.7, this ruler of main-belt asteroids might be tough through binoculars in an urban sky, but the smallest scope easily pulls it in. The Hyades passage is leisurely, making it unlikely that we'll see Ceres move in one observing session. Print out a chart and place a dot on it each time you take your scope out. Avoid the nights of Nov. 18 to 20, when the Full Moon crosses nearby.

The Hyades is one of the closest star clusters to our solar system, 440 light-years in the distance — yet Ceres is barely 90 light-seconds out.

Space rock on your face  



This month, Ceres cuts across the Hyades, sprinkled across the face of Taurus the Bull.

half of the U.S. and Canada. The southern limit line runs from Florida diagonally across the country to Wyoming and into Canada. It's a difficult observation to make because of the Sun's proximity (15° away), so utmost care and past experience of such events are paramount — don't take lightly the risk of exposing your eyes to the Sun. Use a telescope that is well aligned and already calibrated for pointing so that accurate acquisition of the Moon and Mercury is possible. The time of the occultation will vary depending on your geographic location. For example, Mercury disappears at 1:38 P.M. CST in Kansas City, Missouri, and at 2:33 P.M. CST in Chicago.

Mercury is lost in bright

twilight by the second week of November and heads toward its Nov. 28 conjunction with the Sun. It reappears in the evening sky in December.

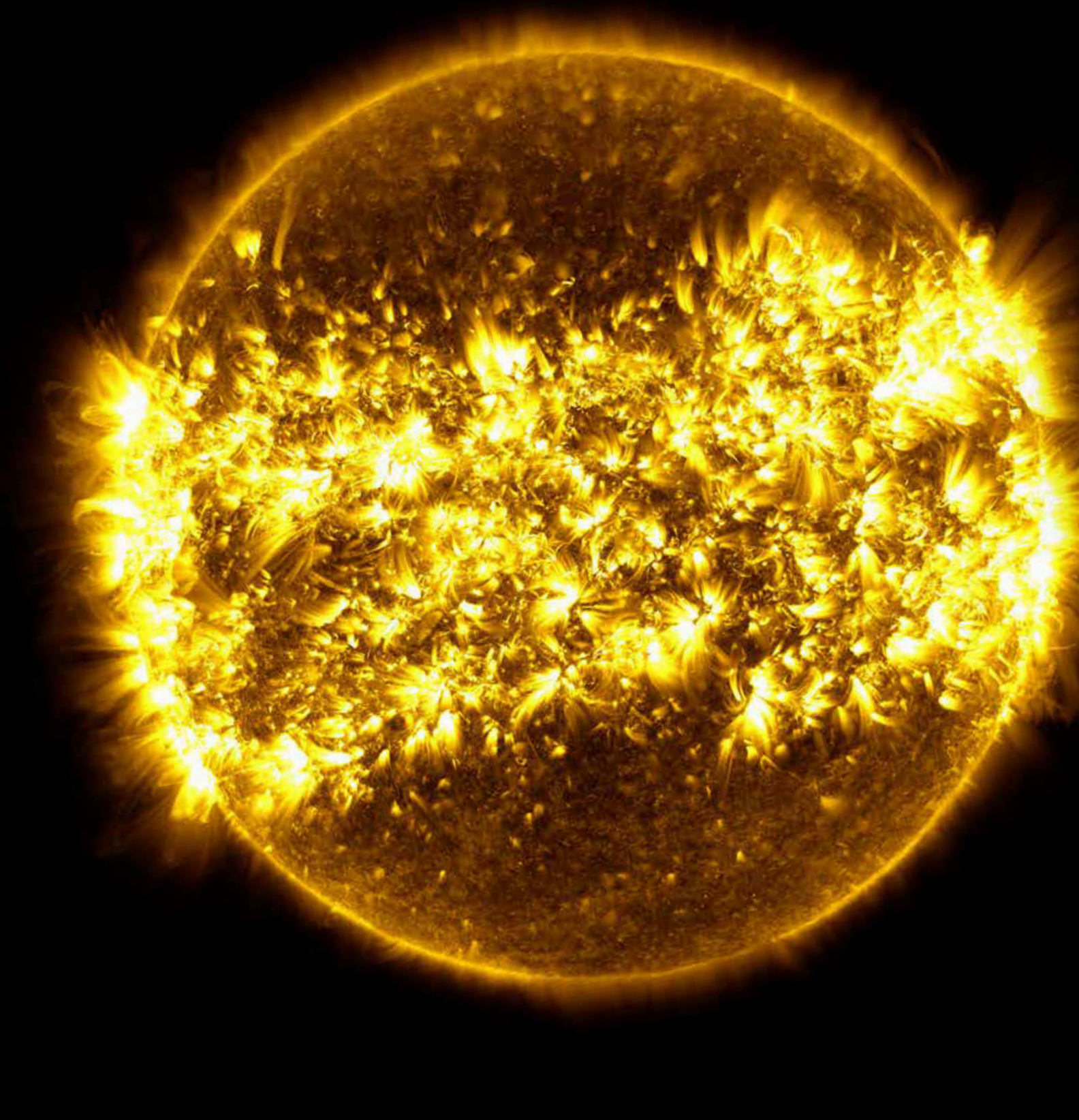
Mars is too close to the Sun to observe during most of November. It has a conjunction with Mercury on Nov. 10, but the pair is low in the sky and at magnitude 1.6, the Red Planet is difficult to see just before sunrise. Mars returns to the morning sky by the end of the month. ☾

Martin Ratcliffe is a *planetarium professional with Evans & Sutherland and enjoys observing from Wichita, Kansas.*
Alister Ling, who lives in *Edmonton, Alberta, is a longtime watcher of the skies.*



GET DAILY UPDATES ON YOUR NIGHT SKY AT
www.Astronomy.com/skythisweek.

Sketching the



SUN with AI

The oldest method of recording the Sun has some new artificial-intelligence tricks. **BY MARK ZASTROW**

ON EVERY CLEAR SOUTHERN CALIFORNIA MORNING, Steve Padilla steps outside his home at Mount Wilson Observatory in the San Gabriel Mountains, overlooking Los Angeles and the Pacific Ocean from an elevation of about 5,700 feet (1,740 meters). Then, he walks to the tallest of the famed observatory's solar telescopes and

ascends 150 feet (46 m) higher.

Atop the historic tower, he stands on a platform that shakes precariously as he leans over to adjust the telescope's flat mirrors. These track the Sun and reflect its light to the scope's objective lens, which projects a 17-inch-wide (43 centimeters) image of the solar disk onto a piece of paper on a table in a ground-level observing room below.

Padilla then descends to that room, and begins to sketch the Sun, recording the dark spots spattered across its gilded disk. It's a ritual that has been observed on nearly every sunny day at Mount Wilson for over 104 years, producing the world's longest running dataset of sunspots.

This used to be the task of staff

astronomers, but in recent years, funding for solar research at Mount Wilson has dried up. Padilla soldiers on as the lone keeper of the flame.

Now, this wealth of data collected by the most old-fashioned of methods is becoming useful to a group of researchers in South Korea who are applying modern techniques in artificial intelligence to it. The team at Kyung Hee University in Seoul have used Mount Wilson's data to train a deep-learning algorithm to try to extract magnetic field data from sunspot sketches. Working from the sketches, the AI renders the Sun as if it were observed by modern satellites. The AI-generated images are not perfect, but they could be used to glean information about the strength of the Sun's magnetic field in those sketched regions.

The work is "very interesting," says Roger Ulrich, the director of Mount Wilson's 150-foot solar tower. "Their first step is obviously to demonstrate that the method basically



Steve Padilla sits at the observing room, making one of his daily sunspot sketches. **STEVE PADILLA**

works — and they did that. So it would be interesting to see how far they can carry it."

Deep learning

In the summer of 1612, Galileo Galilei turned his telescope to our closest star, the Sun, projecting its image safely onto a screen. To his surprise, he found the gilded orb was blotted by small dark spots that moved across its face. Although he was not the first to discover such sunspots, his hand-drawn sketches are still some of the earliest surviving drawings of them.

Today, of course, astronomers

Sunspots produce knots of magnetic fields that glow brilliantly in ultraviolet light. This image is a composite of 23 separate images taken over the course of Jan. 11, 2015 to Jan. 21, 2016 by NASA's Solar Dynamics Observatory, showing the regions that were active during that time. **NASA'S GODDARD SPACE FLIGHT CENTER/SDO/S. WIESSINGER.**
PENCIL: VLAD IVANTCOV/DREAMSTIME

Mount Wilson sketch



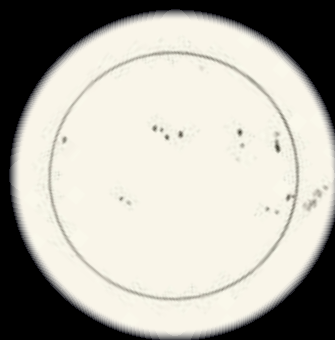
TRAINING AN AI

To “teach” an AI to generate artificial imagery and magnetograms, the Kyung Hee team constructed a training dataset of hand-drawn sketches from Mount Wilson’s archives (an example is at top left) and corresponding satellite images and magnetograms (at left, left column).

The method the team used to train the AI is called a generative adversarial network. The main algorithm tried to generate artificial images based on the sketches that resembled the real data as closely as it could. Then, a second algorithm acted as a sparring partner, pointing out flaws in the first algorithm’s attempts. After about 210,000 training attempts, the AI was able to produce images and magnetograms that looked markedly similar to the actual observations (at left, right column).

Then, the team deployed the model on historical sunspot sketches. Galileo sketched the image at top right of the Sun’s disk on June 2, 1613. The AI-generated images (at right) represent what a Sun-observing satellite might have seen if it were around in Galileo’s time. Each image corresponds to a different wavelength of light.

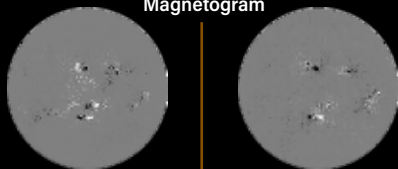
Galileo sketch



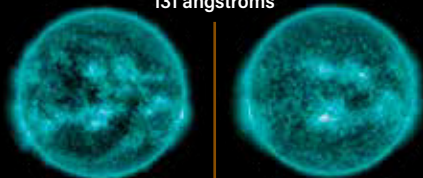
Satellite data

AI-generated images

Magnetogram

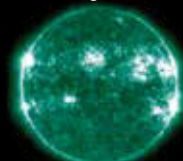


131 angstroms



AI-generated images

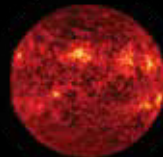
94 angstroms



171 angstroms



304 angstroms

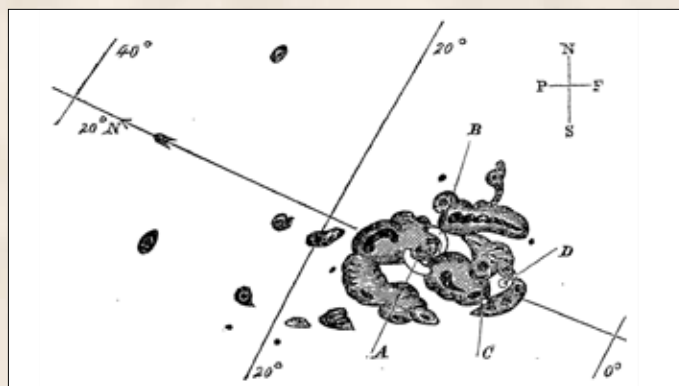


335 angstroms



have much more advanced methods for observing the Sun. Ground-based and satellite imagery capture the Sun in multiple wavelengths, revealing the complex structures of its sunspot-creating magnetic field — details that would have eluded Galileo and his visual observations.

The Kyung Hee team set out to create a program that could tease out some of these details, acting as a bridge between historical records and modern satellite observations. To do so, they used a neural network — an algorithm trained on a large amount of data to learn to perform a task. In this case, the researchers wanted to feed the model with sunspot sketches, which capture only the visual appearance of the Sun’s surface. The algorithm would then spit out the kind of images that NASA’s Solar Dynamics Observatory (SDO)



Amateur astronomer Richard Carrington sketched this group of sunspots on Sept. 1, 1859, noting what he called a “singular occurrence” of “two patches of intensely bright and white light” appearing to break out from the surface of the Sun (marked with the letters A and B). Roughly 18 hours later, a streaking mass of plasma ejected from that region of the Sun plowed into Earth’s magnetic field, causing one of the strongest geomagnetic storms in the modern record.

satellite might capture in various bands of ultraviolet light, where active sunspot regions glow brilliantly.

Those kinds of images can reveal information about the state of the Sun’s magnetic field. That’s because unlike Earth’s magnetic field, which more or less resembles that of a planet-sized bar magnet, the Sun’s magnetic field is a

complex mess of looped and knotted strands that arc above the star’s visible surface. The energy trapped in these twisted magnetic field lines creates sunspots by suppressing energy welling up from within. This makes those areas cooler and, therefore, darker in visible light. But it also heats gas high in the Sun’s atmosphere, creating the

scorching, glowing areas seen in UV images.

“We thought that although sunspot drawings have limited information, if we provide enough data to a deep learning model, it can generate solar images similar to the SDO observation data,” co-authors Harim Lee and Yong-Jae Moon told *Astronomy*.

Sketching tradition

To provide the model with a training dataset, they turned to the Mount Wilson archives.

The tradition of daily sunspot sketches at the facility dates to Jan. 4, 1917, and persisted even through the rise of photographic plates. While Edwin Hubble was using the 100-inch Hooker telescope across the observatory campus to photograph galaxies and prove that they were “island universes” of their own, hand-drawn sketches remained the method of

choice for recording the Sun at the 150-foot solar telescope.

One reason was that photographic plates weren't large enough to capture the full 17-inch-wide image. But observations by eye and hand have other advantages over those early photographs, notes Padilla, especially when the seeing is poor and turbulent air in the atmosphere distorts the image. "Your eye will integrate the detail," says Padilla. "Even if the seeing is not perfect, if you get moments of sharp seeing, your eye will note that and you can draw in that fine detail. Whereas with a photograph, if you had a moment of bad seeing, you'd come up with a blurry image and not much detail."

Lee, Moon, and their colleague Eunsu Park took a set of Mount Wilson sketches drawn by Padilla and other observers from 2011 to 2015 and fed them into the algorithm, along with the actual corresponding UV images from SDO. They also provided the model with same-day SDO magnetograms, which are maps of the Sun's magnetic field strength that indicate the polarity of the field at active regions.

The model, published Feb. 5 in *The Astrophysical Journal*, generates artificial images that are strikingly similar to the real UV images. And in the generated magnetograms, the team found the model is able to reproduce a characteristic signature of active sunspot regions — side-by-side patches of opposite polarity — even though the model has no knowledge of the physics involved.

Next, they turned their model loose on Galileo's sketches. Since he made several weeks' worth of drawings tracking changes in the Sun's surface, the team was able to



STEVE PADILLA

George Ellery Hale, the founder of Mount Wilson Observatory, commissioned the 150-foot solar tower to follow up on one of his most important discoveries — that sunspots possessed strong magnetic fields. The 150-foot length refers to the focal length of the telescope; its 12-inch f/150 primary lens is at the top of the tower, and projects an image to the observing room at ground level.

use the model to calculate how magnetically active these regions were at the time, how they evolved, and how they would look to modern satellites.

Giving Galileo's sketches a facelift isn't the only thing the new model can do. Lee and Moon hope that it can also help them analyze other historically significant solar storms captured in sunspot sketches — like the famous

Carrington event of 1859, which created aurorae seen in locales as close to the equator as Cuba. Understanding these massive solar storms has never been more important: Today, they threaten electrical grids, satellites, and even the safety of astronauts.

Long-term payoff

Ulrich hopes this work is the start of something he had long hoped for. "The idea of going back and kind of resurrecting old global magnetogram structures for the Sun has always intrigued me as something that would be valuable," he says. "The sunspot drawings have some of that information, but obviously not enough of it without this other AI approach."

One limitation of the model, however, is that it doesn't reproduce non-active regions of the Sun with weak magnetic fields, which Ulrich says would be necessary to get a comprehensive picture of the Sun's magnetic field at any given moment, past or present. Though he admits it might not be possible to solve, he says "it certainly would be worth checking out."

Ulrich and his team were forced to cease research at the 150-foot solar tower in 2012 due to equipment failures and

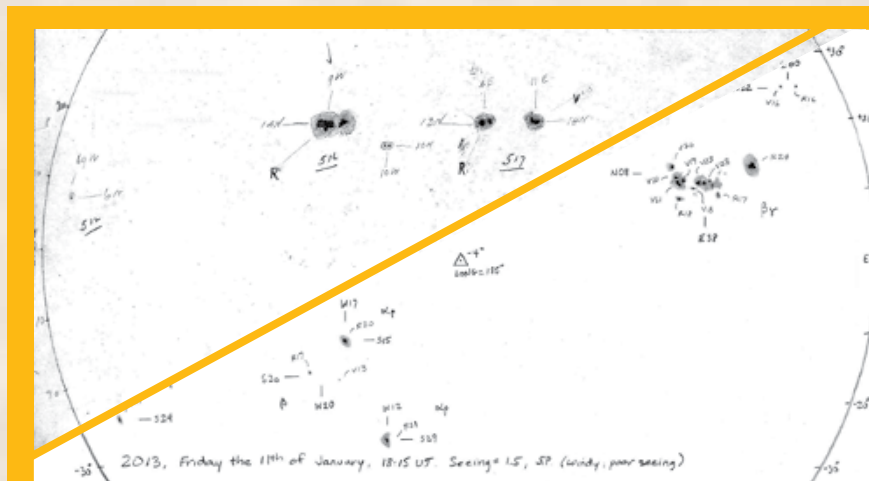
a lack of funding. But he's gratified to see that their efforts to digitize the records have been useful. "That's part of why I wanted to get the drawings out there to people," he says.

In the meantime, Padilla plans to keep living at Mount Wilson and continue his sketches — for as long as he can. The observatory survived a close call with conflagration in the 2019 Bobcat Fire. With the facility nearly consumed by flames, Padilla was forced to evacuate. "I could see the huge plume of smoke every day," he says. "In the evening, you could look up and see the red glow of flames burning."

Then, a few months after he returned, the observatory was shuttered by the COVID-19 pandemic. With the mountaintop bathed in an eerie quiet, Padilla watched bears and other wildlife return. "It was going back to a more natural state," he says.

All the while, he continued his daily routine of opening up the solar telescope and sketching the Sun. "That was a good thing for me in the midst of the pandemic," says Padilla. "It gave me something to persevere with." ☛

Mark Zastrow is senior editor of *Astronomy*.



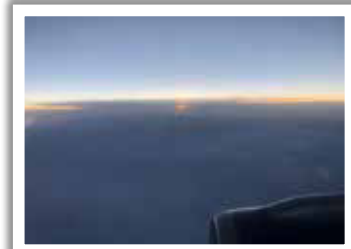
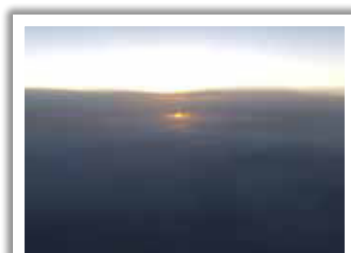
Top: The first daily sunspot sketch at Mount Wilson Observatory was drawn by staff astronomer and solar photographer Ferdinand Ellerman on Jan. 4, 1917. **Bottom:** Padilla drew this modern example on Jan. 11, 2013. MOUNT WILSON OBSERVATORY/UCLA

Flying into June's

RING OF FIRE

Take a journey through the Moon's shadow.

BY JAY M. PASACHOFF



ANNULAR ECLIPSES ARE A SIGHT TO BEHOLD, the Moon inching in front of the Sun until all that's left of our star is a glowing ring. It's no wonder so many ancient civilizations, looking upon the resulting ominous halo, or annulus, of sunlight, believed such an event meant they had angered celestial gods.

As an avid eclipse scientist who was forced to sit out last year's solar eclipses, I was eager to see whatever bit of June's annular eclipse that I could. Unfortunately, continuing travel restrictions prevented me from going to see annularity from the ground. Still, beautiful views of its partial phases were visible from the northeastern half of the continental U.S., so I wasn't alone in heralding the beginning of summer with a blazing partial eclipse.

Above the clouds

I have witnessed 73 solar eclipses in my life so far. But people never forget their

Left, from top: From my seat, I captured first the bright sunrise, and then partial and annular views of the eclipse. JAY M. PASACHOFF; PROCESSED BY ROBERT VANDERBEI

Right: Although annularity was limited to northern Canada, Greenland, and Russia, a partial eclipse was still visible in Toronto, Canada, where it backlit the CN Tower. FELIX ZAI

first. Mine was in October 1959, when I was a freshman at Harvard College. The day promised eclipse-blocking rain, so the observatory director chartered a Douglas DC-3 to avoid missing the event. Lifting off from Boston, we soared above the rain-heavy clouds and for the first time, I witnessed the cosmic wonder that is totality. I have since seen other total solar eclipses from airplanes; it's a wonderful way to experience an eclipse if ground-based viewing is forecast to be poor.

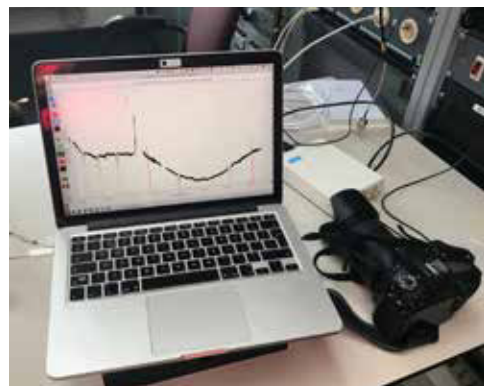
More than 60 years later, I still treasure the opportunities I have to fly through the Moon's shadow. I had originally planned to travel to Qaanaaq (formerly Thule), Greenland, to view June's annular eclipse, but the pandemic meant I was unable to carry out the plan. Although I could not reach annularity on the ground, I was lucky enough to be on a chartered flight arranged by *Sky & Telescope*. Before the

ECLIPSE





In St. Petersburg, Russia, viewers had amazing views of the partial eclipse despite some cloud cover. ELENA ROSCHINA



Astronomers Hans van der Meer and Tammo Jan Dijkema used the Dwingeloo Radio Observatory in the Netherlands (left) to record radio signals from the solar corona (right). HANS VAN DER MEER (2)

Sun rose over southern Canada, our flight departed Minneapolis at 3:15 A.M. CST. Despite some bad weather over western Lake Superior, we had plenty of time to reach the path of 4½-minute annularity. The pilots skillfully maintained our planned heading while banking the plane about 5° to provide a clear view of annularity for those looking over the wing.

My wife and I were in row 10, the only row with two windows. Although the rising Sun itself was shrouded behind clouds

— meaning we missed seeing its apparent “horns” as the Moon slotted into place — the sunrise as a whole was beautiful. Through our solar filters, we had excellent views of the partial and annular phases.

Watching the event, it’s not hard to imagine what ancient people must have thought. But perhaps if they had had the same understanding of eclipses as we now do, they would have looked at these events as the wonder they are instead of as ill omens. I certainly do. ☾



I wasn't alone
in heralding the
beginning of summer
with a blazing
annular eclipse.



Top and above: Qaanaaq, Greenland, one of the most northern towns in the world, had excellent views of the eclipse for the locals able to view it. HALUMI DAORANA (2)

Left: In a moment of serendipity, a bird's flight path takes it in front of the partial eclipse, enabling photographer Zev Hoover to track its sinusoidal motion in this compound image. ZEV HOOVER

HIGH IN THE SKY



FLYING IN AN AIRPLANE wasn't the only way to catch this annular eclipse.

High up on the 86th-floor observation deck of the Empire State Building were a few dozen people who had bought advance tickets to observe the event. According to eclipse enthusiasts Janine and Darren Olah, the crowd held their breath on whether they would have a cloud-free view. "Luck was with us, and we were absolutely thrilled as the eclipsed Sun came into view," Janine Olah says. "First one glowing horn, then the other, and then a beautiful deep crescent."

She suspects more than a few eclipse chasers were born that morning. "It was more spectacular than I could have imagined a partial eclipse to be, blazing over the water and beyond the skyline." — J.M.P.

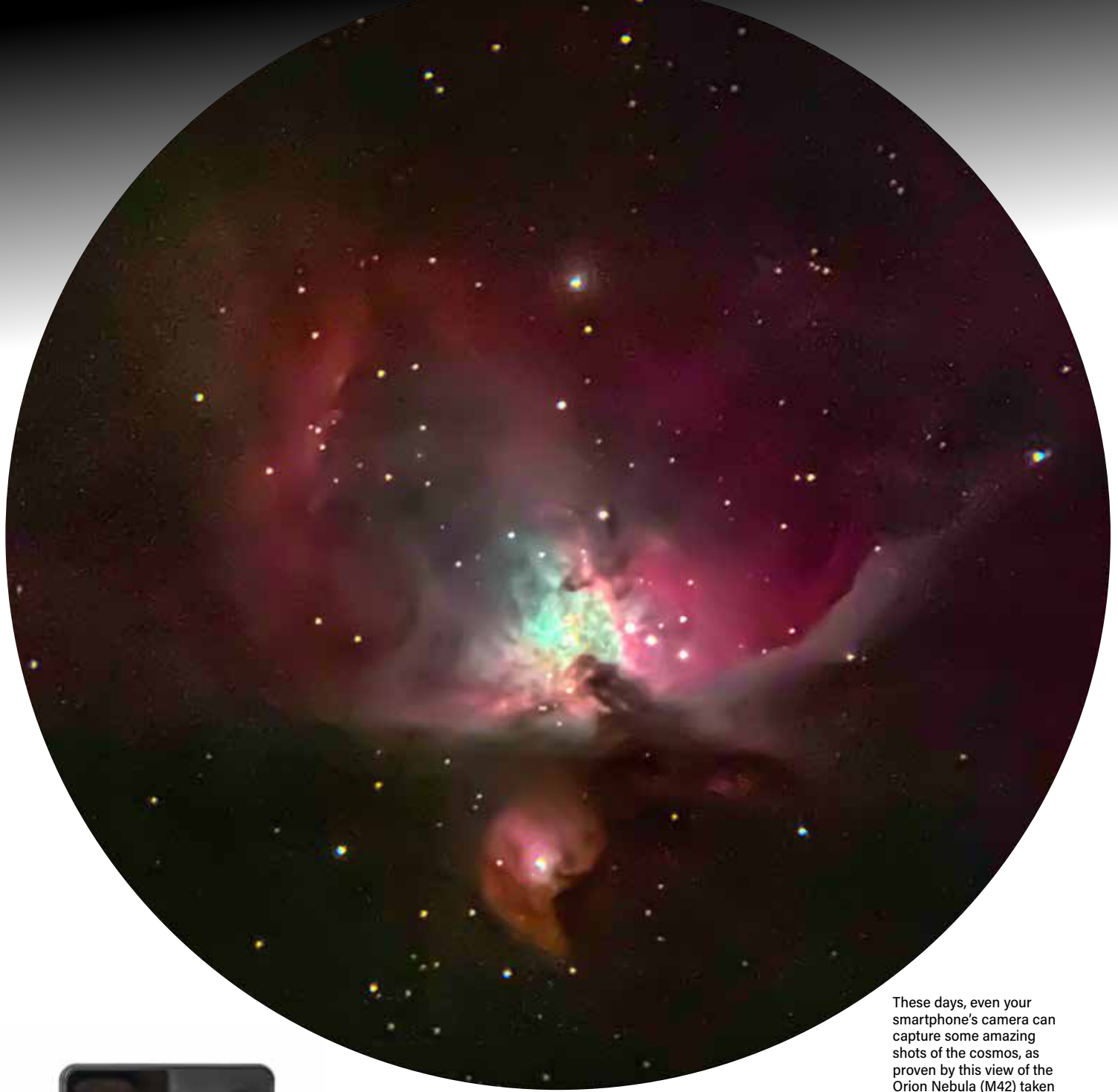


In Boston, Alan Sliski captured this image with nature's filter — clouds — before switching to a solar filter for the total eclipse. AARON SLISKI AND ALAN SLISKI



Thick clouds provided enough cover to capture this image of a plane landing at Logan Airport in Suffolk County, Massachusetts. IMELDA JOSON AND EDWIN AGUIRRE

Jay M. Pasachoff, *Field Memorial Professor of Astronomy and director of the Hopkins Observatory at Williams College, has seen 73 solar eclipses. He has been writing about the Sun for Astronomy magazine since Vol. 1, Issue 1.*



These days, even your smartphone's camera can capture some amazing shots of the cosmos, as proven by this view of the Orion Nebula (M42) taken through a 12-inch telescope.



Astroph

You don't need top-tier equipment to image the night sky through your telescope. Your phone can do the trick. **TEXT AND IMAGES BY MICHAEL WEASNER**

WHEN I WAS 6 YEARS OLD, my older brother helped me kick off my journey to becoming an amateur astronomer by taking me out to our backyard in southern Indiana and giving me tours of the night sky. Besides showing me the Moon, planets, and stars, he pointed out that the constellation Cassiopeia formed my initials: M and W. His passion for the cosmos is what first sparked my interest in astronomy and science in general.

Later, when I was a teenager in 1961, I received my first telescope as a Christmas present from my mother: an Edmund Scientific 3-inch f/10 Newtonian reflector. The following year, I started taking photographs through that telescope using her roll-film box camera — remember those? Over the next several years, I continued taking occasional astrophotos through the modest scope using a 35mm camera.

I earned a B.S. in astrophysics in 1970. However, I never became a professional astronomer. Instead, the degree was my ticket into the U.S. Air Force (USAF), where I served as both a jet fighter pilot and fighter pilot instructor, as well as a manager on the USAF Space Shuttle Program. Working with NASA in the early 1980s to prepare Vandenberg Air Force Base in California to launch and land the Space Shuttle *Discovery* on military missions was the beginning of my space career. After leaving the Air Force, I went on to work at a large aerospace company on several space-related projects.

It wasn't until 1996, however, that I purchased my second telescope: a 3.5-inch f/13.8 Meade ETX Astro Telescope. Shortly after, I began using consumer digital point-and-shoot cameras to image the night sky, later moving

on to digital single-lens reflex cameras with various ETX models and larger telescopes. Though I always considered myself an observer rather than an astro-photographer, I enjoyed experimenting with astroimaging. However, I never got into using dedicated imagers and I rarely connected a computer to my telescopes.

Then, in 2007, Apple released their first iPhone. As soon as I received it, I began to do smartphone astrophotography. And by upgrading my iPhone every two years, I have continued to pursue smartphone astrophotography with increasingly impressive results. To this day, I continue to enjoy using my iPhone to capture amazing images of the night sky with a Meade 12-inch f/8 LX600 telescope in my observatory in southern Arizona.

With a smartphone, the Sun, Moon, planets, asteroids, comets, stars, and even many deep-sky objects can be imaged without needing a connected computer or much, if any, post-processing. Plus, the images you capture can be immediately shared with your family and friends and posted on social media. Smartphone astrophotography also lets you easily record a snapshot of what you see through your telescope's eyepiece. And since you likely already

Simply point and shoot



Zodiacal light



Orion

have a smartphone, why not use it for astrophotography?

Getting started

So, how do you do astrophotography with an iPhone — or any smartphone, for that matter?

In the most basic sense, you just need a capable device. There are many recent smartphone models you can use to take handheld photographs of the night sky that can reveal the Moon, brighter stars, and even some planets. And on later model iPhones, the iOS Camera app in

otography with your smartphone



To take smartphone shots through a telescope, you can either mount the phone or hold it by hand.

“Night Mode” will reduce or eliminate camera movement, letting you take exposures up to 30 seconds when photographing the night sky. For the best results, you should use a smartphone adapter to attach the phone to a camera tripod, a sky-tracking mount, or piggy-back it on a tracking telescope. That will let you take long exposures that reveal the Milky Way, zodiacal light, constellations, and star trails (when tracking is off). There are similar apps on Android phones, too.

The next level of smartphone

astrophotography is attaching your phone to an optical device, such as a spotting scope, binoculars, or a telescope. For bright objects like the Moon, you can simply hold the phone’s camera over the eyepiece and take a photo. But to get the best results, you should attach the phone to the eyepiece using a smartphone adapter, which are available for \$20 to \$100. Most adapters are universal and will fit the majority of smartphone models, so you can likely keep using the same one as you upgrade your smartphone to a newer model. However, other adapters are designed for specific phone

models to accommodate unique sizes and camera lens locations. Some adapters include a ¼"-20 tripod mounting hole. There are some adapters that fit on only 1¼" eyepieces and others that fit on either 1¼" or 2" eyepieces. However, not all adapters will work on every 1¼" or 2" eyepiece, depending on the design and diameter of the eyepiece tube itself.

With only a smartphone attached to an eyepiece and a basic camera app, you can start taking photos of lunar eclipses, lunar craters, planets, the phases of Mercury and Venus, the changing positions of Jupiter’s four bright moons,



Target the varied worlds of our solar system



Lunar eclipse



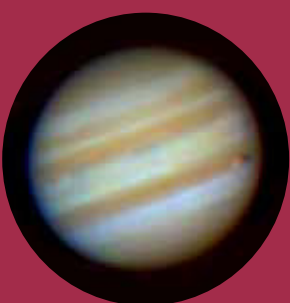
Copernicus crater



Saturn's rings



Venus crescent



Jupiter's clouds

bright asteroids, and countless stars. Add on a safe solar filter, and you can even photograph details on the Sun.

When attempting to snag bright planets, remember that you get the best images by taking a video recording and then stacking all the video frames using an astrophotography stacking program on a computer, such as Lynkeos (Macintosh) or Registax (Windows), both of which are free. Some smartphones allow you to set a fast frame rate, too, letting you capture up to 240 frames per second. With a frame rate that high, you can collect more than 2,000 video frames in just 10 seconds!

Pushing the limits

To photograph fainter objects with a smartphone, you'll need to deploy special apps designed for low-light conditions. Fortunately, some apps include functions specifically designed for smartphone astrophotography.

On my iPhone, I use an app called NightCap Camera. (Note: I have been a beta tester of NightCap Camera for many years.) The app gives you full manual control over your ISO setting (up to ISO 12,500), shutter speed (maximum one second), focus, camera lens selection, and white balance. It also has an intervalometer that allows you to automatically take multiple exposures. Finally, the app has special modes for taking long exposures, letting you capture star trails, satellite passes, and more. On Android phones, the free app DeepSkyCamera is designed for astrophotography and allows for manual exposure control for imaging.

NightCap Camera automatically stacks individual images to build up



Binoculars offer another easy (and affordable) way to enhance your smartphone's view of the cosmos.

longer exposures than normally would be possible on the iPhone. For example, 60 one-second exposures of a faint nebula or galaxy are merged into an image roughly equivalent to a single one-minute exposure. NightCap Camera, however, does not register stars, so an accurate tracking mount or autoguider is required for long exposures. On Android phones, the free app SpiralCam will image and stack faint objects. You'd be surprised what amazing images your phone can capture with long exposures!

Apps such as NightCap Camera will also greatly expand the objects your smartphone can photograph. Star clusters are good initial targets to help you learn how to capture faint objects using your phone. For instance, with a wide-field eyepiece, you can image both members of the Double Cluster (NGC 869/84). Bumping up the magnification will reveal globular clusters like the Great Globular Cluster in Hercules (M13). Bright planetary nebulae like the Ring Nebula (M57) are also good smartphone targets, while fainter ones like the Blue Snowball (NGC 7662) and the Lion Nebula (NGC 2392) are slightly more challenging to capture. Similarly, the Crab Nebula's (M1) low surface brightness makes imaging it a difficult task.

As long as you don't expect Hubble-quality images, your smartphone can also photograph galaxies. However, as with the Crab Nebula, galaxies with low surface brightness are difficult to get good shots of. The bright Andromeda Galaxy (M31), for instance, will only

show its central core and a hint of its spiral arms, even with a wide-angle view. However, taking individual long exposures of galaxies and then stacking the images on a computer can often bring out more details and colors. If your smartphone astrophotography app supports it, using Raw mode will allow more post-processing control and better stacking results. NightCap Camera does not currently support Raw, but it does save images as TIFFs, as well as JPEGs and high-quality JPEGs.

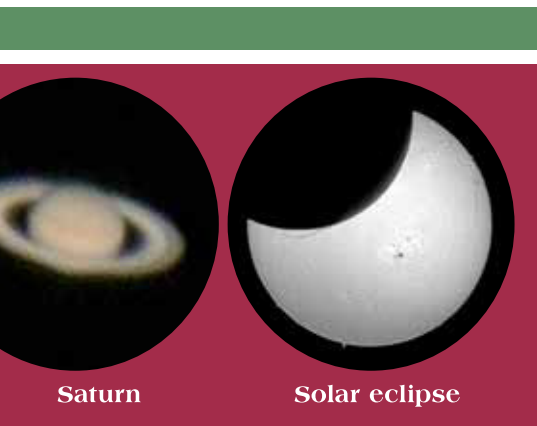
Your phone can also snag many other types of cosmic objects that might surprise you. I suggest letting your imagination go wild. As a general rule of thumb, if you can see it through your telescope, you can probably image it with your smartphone.

Honing your phonecraft

Now that we've covered both beginning and more advanced techniques, here are a few final tips that will help improve your smartphone astrophotography.

Most smartphones allow you to use the volume control on your earbuds to remotely release the shutter, or you can use a Bluetooth-based remote shutter release. When paired with an iPhone, an Apple Watch can also act as a remote shutter release. Using any of these will prevent the blurring that often plagues photographers who rely on manually pressing the on-screen shutter button when taking astroimages with their smartphone, especially long exposures.

Make sure to focus the object in the



Saturn

Solar eclipse



Star trails (as well as satellites or passing planes) are relatively easy to capture with your smartphone by taking long exposures — no telescope or binoculars required. However, you will need to make sure your phone remains motionless while its shutter is open and collecting light.

telescope by physically looking through it before putting the phone camera to the eyepiece. Generally, you should have your camera focused at infinity. And, ideally, you'll want to set up the camera lens at the same distance as the eyepiece's eye relief to maximize the camera's field of view.

But be warned: Aligning the camera lens properly over the eyepiece during afocal imaging — the only way you can use your smartphone for astrophotography through a telescope — is a challenge

with universal smartphone adapters. If you can see the outline of your eyepiece's field of view on the phone's live preview screen, then it's easy to get the camera aligned. However, if you are trying to image a faint object in a dark sky, you may not see anything on your phone's screen at all. Shining a red light into the telescope aperture will help illuminate the field, letting you align the smartphone adapter. Another option is removing the eyepiece — with the adapter and phone attached — from the

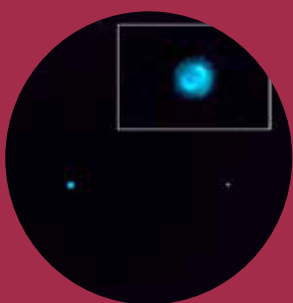
telescope and pointing it at a light source to help you properly adjust it.

The auto-exposure function of some phones and apps may overexpose bright objects like the Moon, Venus, and Jupiter. However, most apps — even built-in ones — will allow you to make some manual adjustments. First, once the view is as crisp as you can make it, lock the focus. Then adjust the exposure to get the best-looking image on the live preview screen that you can and lock the exposure. If the object is still too bright

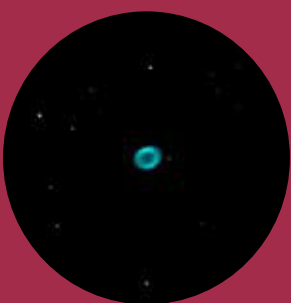
Push the limits by targeting deep-sky objects



Double Cluster



Snowball Nebula



Ring Nebula



Hercules Globular Cluster



Andromeda Galaxy



For the best results when taking long exposures, you should attach your phone to a sturdy tracking mount or tripod using a smartphone adapter.

even after manual adjustments, you can use a Moon filter or a polarizing filter on the eyepiece to reduce the object's brilliance. Finally, as it can be difficult to see if your exposure is correct on the small phone screen, bracket the images using different exposures (ISO, shutter speed) to ensure you get a proper exposure.

Set your telescope to a low magnification and use the phone's "normal" (1x) lens to maximize the brightness of faint objects. Higher magnifications can be used for targeting globular clusters and bright planetary nebulae. Sometimes the smartphone camera's digital zoom or the use of a telephoto lens may improve the image, but these should not normally be employed. Digital zoom just magnifies the pixels without increasing details and a telephoto lens reduces the object's brightness. Implementing a low ISO value and a fast shutter speed is a great approach for targeting bright stars.

Meanwhile, a high ISO value and slow shutter speed — combined with a long exposure and light boost in NightCap Camera — will let you capture fainter nebulae and galaxies.

A clean eyepiece is necessary to avoid dust doughnuts in your image, especially when photographing the Moon. Keeping the eyepiece eyecup attached also helps your shots by preventing stray light from reaching the camera lens, but you might need to remove the eyecup to use some adapters.

The most important advice I can give you is to ensure the smartphone adapter is tight on the eyepiece and that the phone is secure on the adapter — or make sure your phone is insured against damage. As your telescope slews from one object to the next, the phone's position can change significantly, most notably when using an equatorially mounted telescope, making slippage more likely.

Lastly, experiment, experiment, experiment — and do not get frustrated during your first attempts.

Current smartphones have amazing cameras, and apps can further extend their low-light capabilities. This makes smartphone astrophotography accessible to everyone. Join the fun — you might be surprised by what your phone can capture! 📱

Michael Weasner has been imaging the cosmos for nearly 60 years. You can see more of his iPhone astrophotography at www.weasner.com/co.



Jupiter



Albireo



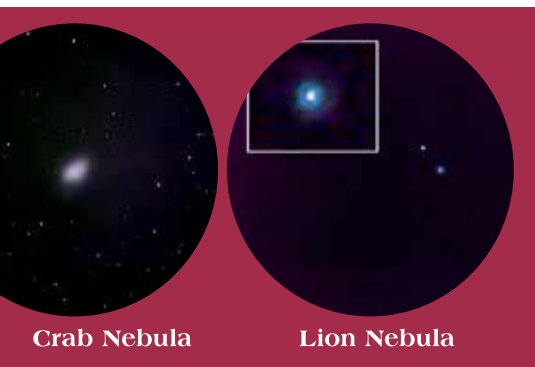
Leo Triplet



The Moon



The Cigar Galaxy



Crab Nebula

Lion Nebula

Catch this month's
**LUNAR
ECLIPSE**



To enjoy a spectacular Blood
Moon, all you need is a clear sky.

BY MICHAEL E. BAKICH

On Friday, Nov. 19, the Sun, Earth, and the Moon (in that order) will line up and most of Moon will trek through Earth's umbra, the darkest part of its shadow. Although this won't be a total lunar eclipse, it'll be darn close. At mid-eclipse, 97 percent of our only natural satellite will be covered by Earth's umbra.

Observers with clear skies should be able to spot nearly all the effects that are visible during a total lunar eclipse. This wouldn't be the case if it were a partial solar eclipse (with 3 percent of the Sun's face uncovered, you would miss out on Bailey's beads, diamond rings, and the solar corona). In other words, we're lucky Luna is the star of this month's show.

Who will see it?

Anyone located on the nighttime side of our planet during this eclipse will catch at least some of it. Observers throughout North America will have the prime views, with only people along the Atlantic coast missing the Moon's passage through the penumbra (the lighter, outer part of Earth's shadow), which usually isn't visible anyway.

South American residents will witness some of the partial eclipse, as will those throughout Australia and central and eastern China. Inhabitants of eastern India and western China will see only some of the penumbral eclipse. Meanwhile, like North America, eastern Russia will have a view of the whole event. Unfortunately, none of the eclipse will be visible for most of Europe and Africa.

When and where?

The start of the eclipse, when the Moon first touches our planet's penumbra, occurs at 1:02:09 A.M. EST. Luna enters the umbra beginning at 2:18:43 A.M. EST and leaves it at 5:47:07 A.M. EST. The eclipse officially ends when the Moon departs the penumbra at 7:03:44 A.M. EST. Greatest eclipse, at which point the Moon is as deep in Earth's umbra as it will get, occurs at 4:02:56 A.M. EST.

The Moon moves through Earth's umbra — from right (west) to left (east) — in this composite assembled from multiple exposures taken during the Jan. 20, 2019, total lunar eclipse. Although this month's event will not be a total lunar eclipse, at 97 percent coverage, it will still be a stunning sight. ALAN DYER

The Moon is fully shrouded by Earth's umbral shadow in this mid-totality shot taken Sept. 27, 2015. ALAN DYER

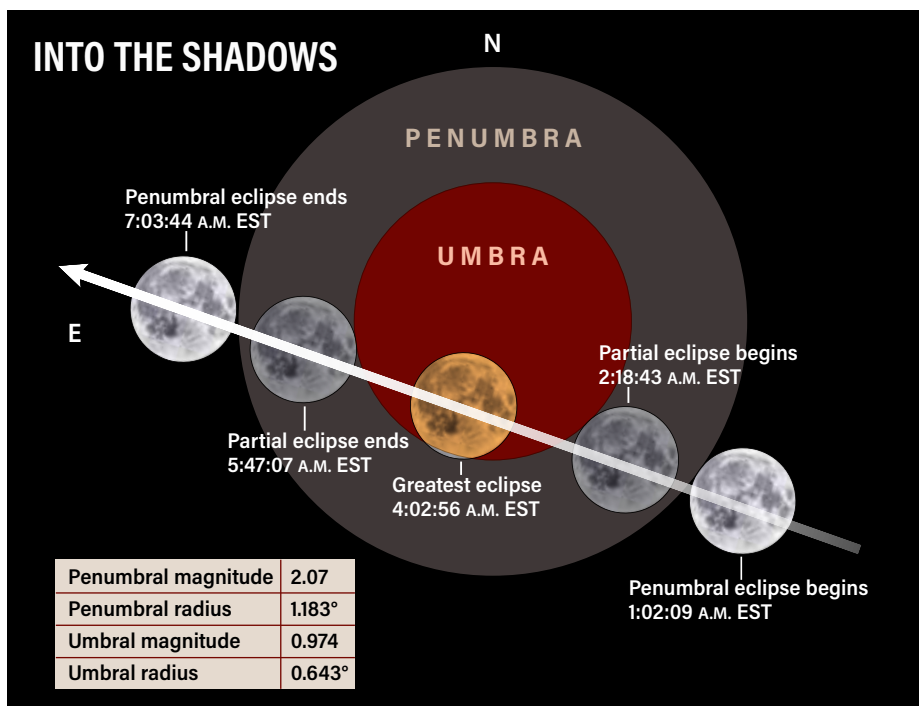


Throughout the event, the Moon will stand in front of the stars of the familiar constellation Taurus the Bull. Our satellite's ever-changing apparent diameter at the time will be nearly 29.47'. That's smaller than its average diameter because this eclipse occurs only 1.7 days before the Moon reaches apogee, the point in its orbit that takes it farthest from Earth. A smaller, more distant Moon takes longer to traverse our planet's shadow. In fact, even though the Moon doesn't pass through the center of Earth's umbra this time, our satellite will still spend nearly 3.5 hours traversing it. And all told, the Moon will spend a whopping 6 hours moving through Earth's penumbra.

Just how dark will this eclipse be?

Ah, here's the question many observers are asking. The eclipse on Nov. 19 will not be total. Some 2.58 percent of the Moon's surface will stay outside

FAST FACT At mid-eclipse, which astronomers often call the instant of greatest eclipse, the Moon will lie overhead at a point in the Pacific Ocean east of the Hawaiian Islands, at approximate coordinates 140° west longitude and 20° north latitude.



DANJON SCALE



0

Very dark, nearly invisible Moon



1

Dark eclipse with a gray- or brown-colored Moon



2

Rust-colored Moon with a darker center and lighter outer edge



3

Brick red Moon, which may have a yellow edge



4

Copper- or orange-colored eclipse, possibly with a bluish rim

The color the Moon takes on during lunar eclipses varies. Astronomers use the Danjon scale to rate the Moon's look, which can run from nearly invisible to rusty red to copper-orange. *ASTRONOMY: ROEN KELLY*

the umbra. Even that region, however, will fall within the darkest part of the penumbra.

If you've ever glimpsed a 3-percent-illuminated crescent Moon, you know its brightness comes nowhere near that of the Full Moon. Remember, though, that a thin crescent reflects sunlight at an oblique angle to our eyes. Indeed, even a Quarter Moon reflects only 10 percent as much light toward Earth as a Full Moon. But during the eclipse, the Sun will be directly behind us, so the illuminated portion of the Moon will be reflecting that sunlight straight back at us.

We also have to account for the part of the Moon covered by the umbra. It won't disappear, but rather should look fairly bright compared to other total lunar eclipses. A good estimate of the Moon's

brightness at mid-eclipse is about magnitude -5 ; it will be brighter than Venus (-4.7), but only 0.1 percent the brightness of the Full Moon.

Because the Moon during this eclipse will pass through a large range of the shadow's depths, its appearance will change significantly with time. For the first half of the eclipse, the umbra will simply appear black. But as it covers more of the Moon's face, the contrast between it and the section remaining in sunlight will lessen.

Our atmosphere also plays a part in how dark any lunar eclipse gets. The air contains water droplets and solid particles like dust and ash, which reduce its transparency. A large volcano erupting before a lunar eclipse can darken the Moon's face considerably by filling the atmosphere with opaque particles. Finally, if there are many clouds along the edge of our planet, not as much sunlight will filter through to the Moon.

In addition to appearing dark, the Moon takes on a particular color before totality. This occurs because Earth's atmosphere bends some of the Sun's rays into Earth's shadow. And because air preferentially scatters the shorter (bluer) wavelengths of that light, it produces a reddening effect while darkening the Moon's face.

Observers estimate the darkness of any total lunar eclipse by using a five-point scale developed in 1921 by French astronomer André-Louis Danjon. He called the brightness of maximum totality (although using the word "darkness" wouldn't be wrong here) the luminosity (L) of the eclipse. You can estimate L with your naked eyes, binoculars, or a telescope. Just be sure to make your evaluation at around 4:03 A.M. EST, which is near the time of maximum for this eclipse.

The five values of L in Danjon's system describe the brightness the Moon's surface during totality. If $L=0$, the Moon is quite dark, almost invisible at mid-totality. If $L=1$, the Moon appears gray or brown, and details are tough to pick out. If $L=2$, the Moon looks deep red or rusty, with those regions nearest the umbra appearing quite dark while those farthest from its center appear brighter, sometimes significantly so. If $L=3$, the Moon's color is brick red and the shadow often has a bright edge that sometimes takes on a yellow hue. Finally, if $L=4$, the Moon is



The photographer captured himself observing a total lunar eclipse from near the Alberta-Saskatchewan border in Canada on Jan. 20, 2019. The Beehive Cluster (M44) sits just to the left of the eclipsed Moon, while Orion is clearly visible toward the right of the frame. *ALAN DYER*



a bright copper-red or orange and the umbra's bright edge often looks blue.

Remember, though, that these numbers are for total lunar eclipses. It's certain that L for this partial eclipse won't be 0, 1, or 2; most observers predict $L=4$. But if it's a bit darker, how many observers will assign it a value of 3? If you do make more than a naked-eye estimate of L , be sure to note the size and magnification of the binoculars or telescope you used and the time. That will help you compare your result with others after the event.

Amateur astronomers probably will go a bit farther than this. If you want to record the event in more detail, start by documenting any changes in color or brightness within different parts of the shadow. Also document the sharpness of the shadow's edge. Especially note how easy it is to see various craters, seas, and mountain ranges in the umbra-covered portion of the lunar surface. As a reminder, this event lasts hours, so you'll have time to do it all.

You even could make a few sketches, which will help you remember the features you saw. Although most people will photograph the event, keep in mind that images don't really capture what your eyes see, while sketches do.

All 'round the Moon

The constellations of the Northern Hemisphere's late fall and winter surround this month's Full Moon. And because the eclipse occurs in the early morning hours in the U.S., the brightest constellations will ride high in the west and south. The Moon will make its coolest close pairing with the Pleiades (M45), which will lie some $5\frac{1}{2}^\circ$ north of our satellite at mid-eclipse. This bright star cluster will appear even brighter as Earth's umbra progresses across the Moon's face. Aldebaran (Alpha [α] Tauri) will lie 14° east of the Moon and the magnificent constellation Orion the Hunter will stand 35° to Luna's southeast.

The sky's brightest star, magnitude -1.46 Sirius (Alpha Canis Majoris), will be 60° from the Moon, standing one-third of the way from the horizon to the zenith. Four more of the sky's top 25 brightest stars to seek out during the eclipse will be Capella (Alpha Aurigae), Castor and Pollux (Alpha and Beta [β] Geminorum, respectively), and Procyon (Alpha Canis Minoris).

A "totally" safe event

Often, when we hear or read the word eclipse, it's followed by some kind of

A total lunar eclipse stands above a blanket of clouds wafting off a peak of the Continental Divide in the Canadian Rocky Mountains of southwest Alberta. The photographer captured this shot just before dawn on Jan. 31, 2018, as the eclipsed Moon was setting in the west. ALAN DYER

warning to protect your eyes. That's an important disclaimer for solar eclipses, but a lunar eclipse is not dangerous in any way. Your eyes are safe because you're simply watching the Moon pass through Earth's two-part shadow. You might also get a better view through binoculars or a telescope — no filter required — which are both totally safe to use for this event.

Do note, however, that for most of the U.S., the early hours of Nov. 19 will likely be cold, so bundle up. It also might be a tough sell to throw a viewing party for this eclipse. But if you're looking for one, lots of astronomy clubs and science centers will be hosting them.

This eclipse showcases easy science that comes from what I like to call sublime celestial geometry. So, head outside for at least a short time to watch our planet line up with its most significant cosmic neighbors. Enjoy the show! ☾

Michael E. Bakich is a contributing editor of *Astronomy* who seeks out any eclipse he can — be it solar or lunar.

Ice fishing

You'll need a steady hand to catch these planets.



Astrophotographer Richard Bosman captured this image of Uranus using a Baader R Longpass filter and ASI 224 MC camera. RICHARD BOSMAN



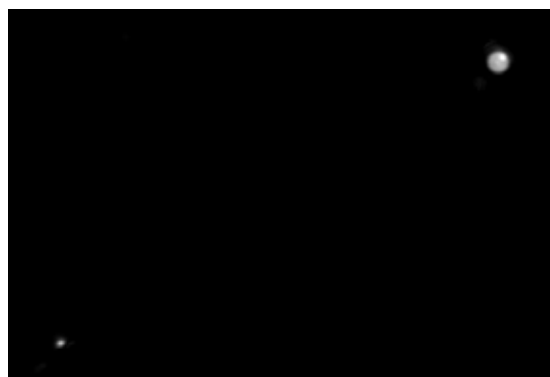
Many readers have written me to say that they enjoy observing challenges. So this month, I'm giving you not one, but two to tackle. Have you ever looked for our solar system's two most distant planets, Uranus and Neptune? Both are visible in tonight's sky and are bright enough to spot through most binoculars — if you know where to look.

Let's start with **Neptune**, which is high in the east as night falls, having passed opposition in September. It is currently located in a barren portion of eastern Aquarius. To find it, first locate by eye alone the Great Square of Pegasus and the bright star Fomalhaut (Alpha [α] Piscis Austrini). Once you spot both, aim your binoculars about halfway between the two. Scan slowly until you come to a distinctive obtuse triangle formed by the 4th- to 5th-magnitude trio of Psi¹ (ψ¹), Psi² (ψ²), and Psi³ (ψ³) Aquarii. They create a pretty little asterism through binoculars and may be visible without binoculars under dark skies as a fuzzy patch.

Without moving the aim of your binoculars, look for 5th-magnitude Chi (χ) Aquarii, a pale red star about 1.5° northwest of the Psi trio. Another, slightly brighter red star appears 1.5° farther northwest still. That's 4th-magnitude Phi (φ) Aquarii. Both of these red giants create a nice color contrast with the true-blue ice giant Neptune.

Right now, Neptune is 3° east-northeast of Phi. In fact, you can probably squeeze the planet as well as Chi, Phi, and the Psi trio all into your view. Of course, there are also several faint stars in the field that could be confused for Neptune. Which one is the planet? I'll give you a hint: the giveaway is the color. Except for reddish Chi and Phi, all the stars in view will appear white. When you finally do identify bluish Neptune, you have found the most distant solar system member that is visible through binoculars. At midmonth, it lies 2.7 billion miles (4.4 billion kilometers) from Earth. The light you're seeing tonight reflected off the planet's cloud tops over 4 hours earlier.

Our second planetary conquest this month lies closer to home and farther east along the ecliptic. The



Neptune's largest moon, Triton (at lower left), sits close to the icy world in this 2017 image. MARC DELCROIX

other ice giant, **Uranus**, is currently 1.9 billion miles (3.1 billion km) from Earth, residing within the borders of Aries the Ram. It reaches opposition Nov. 2, making now a great time to spot it. Even though it is two magnitudes brighter than Neptune, Uranus may prove more difficult to find because there are no distinctive star patterns nearby. But that's okay. Half the fun is the thrill of the hunt.

As you can see from this issue's Star Dome (page 34), Uranus is far removed from Aries' four-star pattern. Therefore, it is probably best to start our quest from the hexagonal head of the Whale asterism in neighboring Cetus to the south. The head is comprised of Menkar (Alpha), Lambda (λ), Mu (μ), Xi² (ξ²), Nu (ν), and Gamma (γ) Ceti. The pattern spans nearly 6° by 10°. Although that is too wide to squeeze into a single field, binoculars will come in very handy to spy the asterism from suburban and urban skies due to the dimness of its stars.

Can you spot our solar system's two most distant planets, Uranus and Neptune?

Menkar, the brightest of the bunch at magnitude 2.6, is a red giant star and so should put on a ruddy appearance through binoculars. It teams with blue-white 93 Ceti just 16' to its north to create an attractive binocular double star.

Aim toward Mu Ceti, the northernmost star in the head. Placing Mu toward the southern edge of the field of view will put 5th-magnitude 38 Arietis near the center. Moving 38 toward the southern edge will put

6th-magnitude Omicron (ο) Arietis near the center. You'll notice Sigma (σ) Arietis just over 1.5° to its east and another greenish 6th-magnitude point about 1° to its west. That's Uranus. Don't confuse Uranus with 29 Arietis, which is about a degree farther west. All four points here — Omicron Arietis, Sigma Arietis, 29 Arietis, and Uranus — appear about the same brightness. But only Uranus will look green.

I would enjoy hearing from readers who spot either or both ice giants through their binoculars. Contact me through my website, philharrington.net. Until next month, remember that two eyes are better than one. ♀



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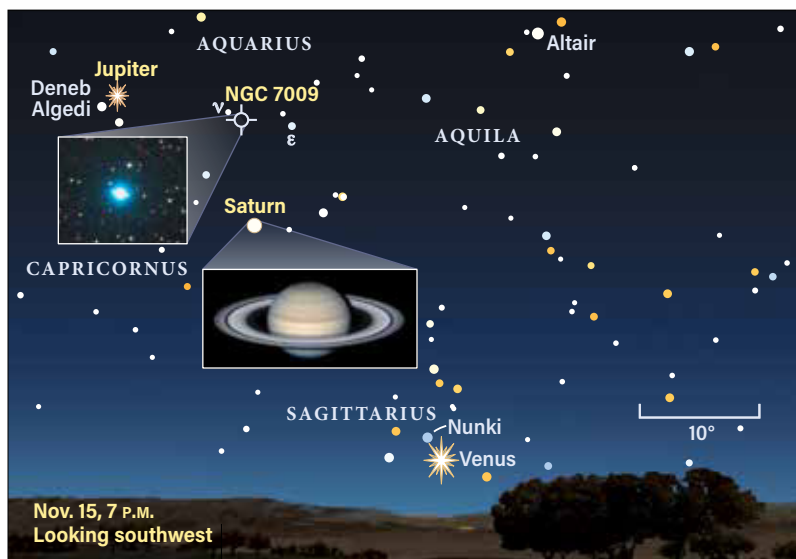


BY PHIL HARRINGTON

Phil is a longtime contributor to *Astronomy* and the author of many books.

Saturns unite!

Catch both the planet and the nebula.



Saturn shares the sky with its nebulous counterpart this month. The Ringed Planet currently sits 0.00016 light-years from Earth. Meanwhile, the planetary nebula NGC 7009 (the Saturn Nebula) is located some 4,300 light-years away. MAP: ASTRONOMY ROEN KELLY. SATURN: ANTHONY WESLEY. SATURN NEBULA: DAN CROWSON



BY GLENN CHAPLE

Glenn has been an avid observer since a friend showed him Saturn through a small backyard scope in 1963.



This month, we voyage to a pair of Saturns — first the planet, then its namesake nebula. The planet currently resides in the constellation Capricornus, while the Saturn Nebula is conveniently located about 10° north-northeast in Aquarius. Both are positioned in the southwest sky after sunset.

Saturn reached opposition back in early August, but it's still an impressive telescopic sight. In last month's column, we toured the constellation Lyra with a 60mm (2.4-inch) refracting telescope. And with this same modest instrument and a magnifying power of just 30x, you can glimpse Saturn's fabled rings. Because its glimmering rings are currently tilted at an angle of about 20°, Saturn resembles a flying saucer in a 1950s sci-fi movie. If the seeing conditions are ideal, increase magnification to 100-120x (the maximum useful power for a 2.4-inch scope) to reveal the rings so-called Cassini division, a dark gap in Saturn's rings. The Cassini division, as well as Saturn's subtle cloud belts, are more readily seen in scopes with twice the aperture and larger.

According to NASA, Saturn has 82 moons. Most of those are beyond the reach of backyard scopes, but a handful can be captured with small instruments. The easiest is Titan, that 8th-magnitude "star" visible in the same low-power field as Saturn. If you view Saturn and Titan nightly for a 16-day period, you can even track the moon through a complete orbit.

Saturn's second largest moon, Rhea, is more

challenging. It's more than a magnitude fainter and never farther than two ring diameters from Saturn. To snare Rhea, wait for an evening when the moon is far off to Saturn's side and seeing conditions allow for maximum small-scope magnification. If you can wait until 2025, Saturn's rings will appear almost edge-on, cutting down on the planet's overall glare. These tactics will likewise work if you're attempting to target Saturn's next two brightest moons: Tethys (magnitude 10.3) and Dione (magnitude 10.4). The annual RASC *Observer's Handbook* includes a handy diagram showing the configurations of these satellites for any night of the year.

When you're done admiring Saturn and nearby Jupiter — the latter shares Capricornus with Saturn; were you really going to ignore it? — turn your scope towards the Saturn Nebula. At magnitude 8.3, it's too faint for the unaided eye, so you may want to use a telescope for this one. If your scope has GoTo technology, you can also simply key in its coordinates: R.A. 21h 04m 11s, Dec. -11° 21' 49". If it comes with a bonus deep-sky database, just punch in "Saturn Nebula" or "NGC 7009" and let your scope take you there.

For the die-hard star-hopper, the path to the Saturn Nebula begins at Nu (ν) Aquarii, a 4.5 magnitude star located about a degree to the east. With a low-power eyepiece in place, center Nu in the field and get it in sharp focus. Since you'll want to move westward (the same way Nu is drifting across the field), move ahead of the star and continue about one degree (two Moon diameters) until an 8th-magnitude "star" enters the field. This should be the Saturn Nebula. To make sure, switch to a medium power (60-75x) eyepiece and play with the focus. If you get a crisp stellar image, it's just a star and you'll have to return to Nu to try again. If you instead see a small fuzzy ball, you've found the Saturn Nebula!

For the die-hard star-hopper, the path to the Saturn Nebula begins at Nu (ν) Aquarii.

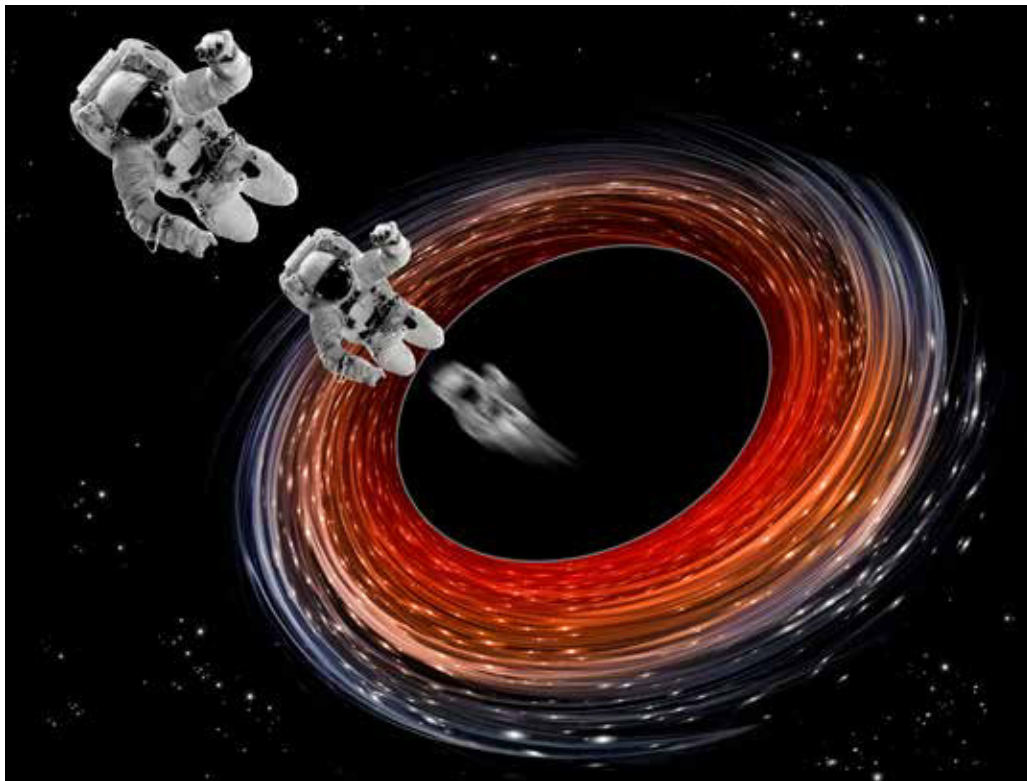
If you're viewing the nebula with a modest scope, you might ask how it got its nickname. True, it's about the same apparent size and shape as the planet Saturn. But it's also bluish — and where are the rings?! The Saturn Nebula's rings exist in the form of sideways extensions, or ansae, that indeed resemble the planet when viewing its rings edge-on. To see the Saturn Nebula's "rings," though, you'll need a bigger scope. A 10-inch with a magnification of 250x should do the trick.

Like other planetary nebulae, the Saturn Nebula formed during the death of an average-sized star like the Sun. As its core collapsed, the star's outer layers were blasted into space. But because this gaseous shell is still expanding and dissipating, the Saturn Nebula will only be visible for a few more thousand years. That might seem like a long time, but it's really just a cosmic blink of an eye.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: The psychology of skygazing. Clear skies! ☿



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A distant observer would never actually see someone cross into the event horizon of a black hole, according to Einstein's theory of relativity. *ASTRONOMY: ROEN KELLY*

Black hole spaghetti

Q | I'VE ALWAYS UNDERSTOOD THAT, ACCORDING TO GENERAL RELATIVITY, A DISTANT OBSERVER OF SOMEONE WHO FALLS INTO A BLACK HOLE WOULD SEE THEM SLOW DOWN, THEN COME TO A VIRTUAL STOP AT THE EVENT HORIZON AND BECOME "SMEARED." SO HOW IS IT THAT LIGO CAN RECORD TWO BLACK HOLES COMBINING IN MILLISECONDS?

*Kevin Hooper
Calgary, Alberta*

A | Let's consider GW150914, the first binary black hole merger detected via gravitational waves. The final black hole formed during the merger is 60 times the mass of the Sun, which means that its size is about 124 miles (200 kilometers) across. This is the typical size of the remnants from black hole mergers that we observe through gravitational waves with the Laser

Interferometer Gravitational-wave Observatory (LIGO).

Now, how is a pulse of light sent by someone falling into a black hole different from the gravitational waves emitted during a merger? Optical light has a wavelength — the distance between two crests of a light wave — of about 1,000 nanometers (a strand of hair is about 90,000 nm wide). For someone falling into the black hole and sending out that pulse of light, the light will be emitted from some location close to the event horizon, or point of no return.

Gravitational waves, on the other hand, cannot be traced to a specific origin in the region of space-time around the black holes. This makes more sense when we look at our example signal. The waves produced during GW150914 have a wave-

length of 1,864 miles (3,000 km), which is larger than the size of the system!

In other words, the main difference between gravitational waves and pulses of light is that the former can be thought of as being emitted from the entire dynamical, vibrating space-time around the merger of two black holes. They do not correspond to any particular location, such as the black hole event horizons, where gravity is so strong that not even light can escape.

Katerina Chatzioannou

Assistant Professor of Physics, California Institute of Technology



Scientists with the Antarctic Search for Meteorites program collect a meteorite in Antarctica's Miller Range. *NASA/JSC/ANSMET*

Q | DO METEORITES
EMIT A HIGH
DEGREE OF RADIATION
WHEN THEY FALL
TO EARTH? SHOULD
PRECAUTIONS
BE TAKEN WHEN
HANDLING THEM?

Wade Carmen
Cleveland, Tennessee

A | On average, around 500 meteorites fall to Earth each year. Any radioactive elements contained in a meteorite are no more significant than in ordinary terrestrial rock. Although meteorites aren't harmful to humans, we can actually be pretty harmful to them.

Our hands are covered in oils and microbes, both of which can contaminate the meteorite and degrade its surface.

Whether you're actively looking for meteorites or happen upon one, you should handle it with care. You can pick it up with clean gloves, tongs, or even aluminum foil. Once you've collected your space rock, keep it in a clean and dry place. A zip-close bag is a perfect way to protect it from humidity.

That said, it can be a bit tricky to know if you've actually found a meteorite. You can ask yourself a few simple questions to determine whether you've found a meteorite or a meteorwrong:

- Is the specimen black or brown and smooth, with no holes or bubbles on the surface?
- Is the specimen solid and compact?
- Is the specimen heavy compared to "normal" rocks of the same size?
- Is the specimen entirely made of metal, or does it show metallic specks on parts of a broken, cut, or polished surface?

If you've answered yes to all of these questions and are interested in learning more about your sample, you should contact your local geological survey office, university geology department, or natural history museum for help identifying your specimen. The Robert A. Pritzker Center at the Field Museum in Chicago also has a meteorite identification outreach program.

Caitlyn Buongiorno
Associate Editor



Q | THE WORD *DUST* COMES UP
OFTEN IN DESCRIPTIONS OF
GALAXIES AND ELSEWHERE. WHAT IS
THE NATURE OF DUST?

Isaac Turiel
Berkeley, California

A | To most people, dust can be any combination of small particles of soil, rock, human skin, human or animal dander, pollen, and tiny bits of fiber. But space dust is different from the dust we're familiar with here on Earth.

Astronomers are also talking about small grains of material when they talk about dust, but unlike on Earth, a majority of those grains consist of carbon and silicates. These materials are primarily born from the winds of evolved stars or supernova explosions.

Astronomers can categorize dust based on where they see it. The first category is dust between galaxies, known as intergalactic dust. The second is in the space between stars within galaxies, or interstellar dust. And the third is interplanetary dust, which, as the name may suggest, can be found between planets in solar systems.

In the case of interplanetary dust, the grains usually also contain a mixture of local ingredients added to the mix mentioned above. For instance, collisions between planets and asteroids early in the system's history contribute to interplanetary dust clouds. Comets also add their own twist as they travel close to their star. This heats up the comet, vaporizing its ice and releasing dust along its orbit.

Caitlyn Buongiorno
Associate Editor

Clouds of dust and gas hide the center of the Milky Way from optical telescopes.

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SEND US YOUR QUESTIONS

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Cosmic portraits



1. URBAN JUNGLE

Star trails illuminate the sky above Park-e Jangali (Forest Park) in the hills overlooking Urmia, Iran. This image is a stack of 110 shots of 20 seconds each, taken with a Canon EOS 6D at ISO 3200 and Samyang 14mm lens at f/4. • **Nima Asadzadeh**

2. FOWL WEATHER

Cygnus hosts the Pelican Nebula (IC 5070, right) and the North America Nebula (NGC 7000, left), separated by a broad, dark dust lane. The imager took five hours of exposure with a 70mm refractor and a 26-megapixel one-shot color camera. • **Martin Nappert**



SEND YOUR IMAGES TO:

Astronomy Reader Gallery, P.O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.





3

3. COSMIC SHORE

The Nubble Lighthouse at Cape Neddick, Maine, casts its light over the waters of the Gulf of Maine and under the arc of the Milky Way. This photo is a panorama of five 25-second exposures taken with a Canon EOS 6D at f/2.8 and ISO 4000. • **Chris Cook**



4

4. FROM SEA TO SEA

The mighty Caucasus (top) and Apennine (bottom) mountain ranges rise out of the lunar sea of Mare Imbrium to the west (at left) and tower over Mare Serenitatis to the east. The lunar Alps appear at upper left. Hadley Plain, the landing site of Apollo 15, is visible just right of center on the northern end of the Apennines, tucked into a valley on the western side of the range. This view is a stack of 1,000 images out of 5,000 taken. • **Burley Packwood**



5

5. GALACTIC KNOT

The Topsy Turvy Galaxy (NGC 1313) lives up to its name, with spiral-ish arms contorted and bursting with star formation. This could be explained by a gravitational encounter with another galaxy, but strangely, there are no candidate galaxies nearby, making NGC 1313's unkempt appearance a mystery. This LRGB image was produced with a 0.5-meter reflector, and two hours and 35 minutes of total exposure. • **Bernard Miller**



6

6. HEART OF THE SOUL

While the Soul Nebula (IC 1848) in Cassiopeia is often pictured with its neighbor, the Heart Nebula (IC 1805), this image is a close-up examination of the light and shadow that do battle in the Soul. Emission nebulae, reflection nebulae, and dark nebulae all feature prominently. Also visible are Bok globules — dark droplets of gas and dust condensing into newborn stars. The photographer used a 10-inch telescope and a ZWO ASI1600MM Pro camera to take nearly 16 hours of exposure time in the Hubble palette. • **Alex Roberts**



7

7. SEXTANS TRIO

NGC 3169, NGC 3166, and NGC 3165 (left to right) are an interacting group of galaxies in Sextans roughly 75 million light-years away. NGC 3169's disk appears to be warped from an encounter; this may also have affected the appearance of lenticular galaxy NGC 3166, which features a visible bar, bulge, and disk. The image represents about 30.5 hours of LRGB exposure. • *Walter Lickteig/Mike Selby*

8. PAINT THE TOWN RED

In February, the Empire State Building's upper levels were bathed in red light, in partnership with NASA's Jet Propulsion Laboratory, to honor Perseverance's landing on Mars. The photographer was able to capture the display alongside a crescent Moon. • *Chirag Upreti*

9. PINCER MOVEMENT

The Lobster Claw Nebula (Sharpless 2-157, at left) appears set to grab the Northern Lagoon Nebula (NGC 7538, at bottom), while the Bubble Nebula (NGC 7635, at right) looks on in this wide-field image. The photographer used an 8-inch scope and over 13 hours of exposure in the Hubble palette. • *Chuck Ayoub*



8



9

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INDEX of ADVERTISERS

ADM Accessories	65
Armstrong Metalcrafts.....	3
Astro-Physics.....	3
Astronomy Flashcards	65
Bob's Knobs.....	65
Celestron.....	68
Firefly Books, Ltd.....	2
Deep Space Mysteries 2022 Calendar	6
iOptron	3
Metamorphosis Jewelry Design.....	65
Oberwerk	65
Precise Parts.....	65
Procyon Works, LLC.....	65
Rainbow Symphony	65
Revolution Imager.....	3
Scope Buggy	3
Stellarvue	67
Technical Innovations	3

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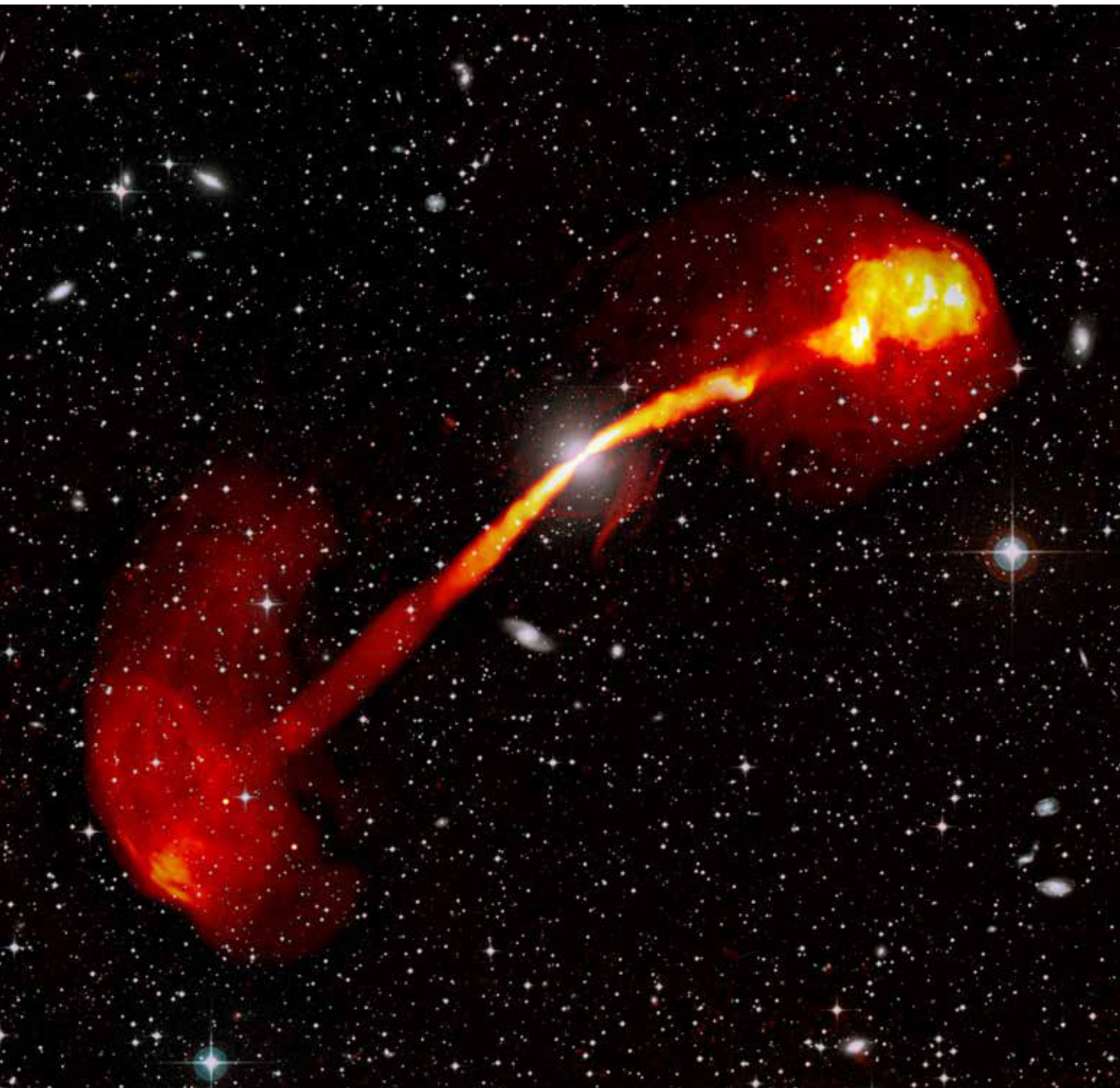
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A GLIMPSE INTO THE FUTURE

Radio astronomy is destined to enter a new era later this decade when the Square Kilometre Array (SKA) comes online. A hint of its possibilities emerges in this stunning image of galaxy IC 4296 made with the MeerKAT radio array, a precursor to SKA that eventually will be folded into the larger instrument. With 64 antennas, each 13.5 meters in diameter, spread across several miles of South Africa's Northern Cape province, MeerKAT delivers an unprecedented combination of sensitivity, resolution, and dynamic range. IC 4296 lies 160 million light-years from Earth in the constellation Centaurus. The orange and red colors in this portrait reveal the galaxy's two bright radio jets as well as fainter ribbons connecting them to giant radio lobes. Also note the wispy threads of radio emission just below the galaxy's center. SARAO/SSS/S. DAGNELLO AND W. COTTON (NRAO/AUI/NSF)



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OPT Telescopes - 800.483.6287 - optcorp.com

Woodland Hills - 888.427.8766 - telescopes.net

Adorama - 800.223.2500 - adorama.com

Focus Camera - 800.221.0828 - focuscamera.com